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Comparison of cortical bone trajectory versus pedicle screw techniques in lumbar fusion surgery

A meta-analysis

Jing-Nan Hu, MD, Xiao-Feng Yang, MD, Chuan-Ming Li, MD, Xin-Xin Li, MD, Yun-Zhi Ding, MD*

Abstract

Background: Biomechanical studies have demonstrated that cortical bone trajectory (CBT) screw can provide a 30% increase in uniaxial yield pullout load than pedicle screw (PS). In addition, the insertion torque of CBT screw is 1.71 times higher than that of PS. A meta-analysis was conducted to evaluate clinical results between CBT screw technique and PS technique in lumbar fusion surgery.

Methods: An extensive search of literature was performed in PubMed, Embase, the Cochrane library. The following outcomes were extracted: visual analog scale (VAS), Oswestry disabilities index (ODI), Japanese Orthopaedic Association (JOA) score, complications, fusion rates, hospital stay, incision length, blood loss, and operation time. Data analysis was conducted with RevMan 5.3 and STATA 12.0.

Results: A total of 12 studies were included in the final analysis. The results indicated that CBT group with less blood loss [$P < .01$], less hospital stay [$P < .01$], and less incision length [$P < .01$] than PS group. There were no significant differences between 2 groups in other clinical parameters and outcomes.

Conclusion: CBT technique provided similar clinical outcomes and fusion rates compared to PS technique in lumbar fusion surgery. However, CBT technique provided additional benefits of less blood loss, less hospital stay, and less incision length.

Abbreviations: CBT = cortical bone trajectory, CI = confidence interval, JOA = Japanese Orthopedic Association, MD = mean difference, ODI = Oswestry disabilities index, PS = pedicle screw, RR = relative risk, VAS = visual analogue score.

Keywords: cortical bone trajectory, fusion, lumbar, meta-analysis, pedicle screw

1. Introduction

Lumbar fusion has been widely used to address certain lumbar pathologies including lumbar stenosis, degenerative disk disease, trauma, deformities, and neoplasms.[1–4] Pedicle screw (PS) technique has been recognized as an irreplaceable instrument in fusion surgery of lumbar spine due to its biomechanical advantage including three-dimensional fixation and short-segment fixation.[5–7] The traditional insertion pathway of PS is transpedicular lateral to medial trajectory. The initial insertion point of PS is the junction of the transverse process and lateral wall of the facet.[8,9] However, several complications are associated with PS technique including long incisions, significant muscle dissection, neurovascular injury, superior facet joint violation, and screw loosening particularly in patients with osteopenia or osteoporosis.[10,11]

Cortical bone trajectory (CBT) screw technique was first described by Santoni et al.[12] The initial insertion point of CBT is the junction of the superior articular process and pars, which allows for minimal soft tissue dissection and may reduce the risk of neurovascular injury. CBT involves caudocephalad path and medial-to-lateral path with the objective of maximizing cortical bone contact through the pedicle to the vertebral body and minimizing the risk of instrumentation failure.[13]

Since the introduction of CBT, several biomechanical studies have supported its viability for pedicle fixation.[14,15] Furthermore, several clinical studies have compared outcomes and complications between 2 techniques.[11,16–28] However, there is no clear conclusion on which technique, CBT or PS, is better. Therefore, we performed a meta-analysis to evaluate the clinical results between CBT screw technique and PS technique in lumbar fusion surgery.

2. Materials and methods

2.1. Ethics statement

As all analyses were based on previously published studies, ethical approval was not necessary in this review.

2.2. Search strategy and study selection

An extensive search of literature was performed in PubMed, Embase, and the Cochrane library up to February 1, 2019. The language was restricted to English and only the published articles

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JNH and XFY were contributed equally to this work.

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Department of Orthopaedics, Xuzhou Cancer Hospital, Xuzhou, China.

* Correspondence: Yun-Zhi Ding, Department of Orthopaedics, Xuzhou Cancer Hospital, No. 131 Huancheng Road, Xuzhou 221000, China (e-mail: doctordingyz@sohu.com).

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were included. The following terms were used in our search: "cortical bone trajectory", "CBT", "medial-lateral superior trajectory", "traditional trajectory", "pedicle screw", and "lumbar". The reference lists of included studies were also hand-searched for additional qualified studies.

2.3. Inclusion and exclusion criteria

Studies were included if they met the following criteria:

1. Participants: patients with spinal disease which need lumbar fusion.
2. Interventions: the intervention in the experimental group was CBT screw technique.
3. Comparisons: the intervention in the control group was PS technique.
4. Outcomes: JOA, ODI, VAS, complications, fusion rates, hospital stay, incision length, blood loss, and operation time were collected as the outcomes.
5. Study design: prospective comparative study, retrospective comparative study, and randomized controlled study.

The exclusion criteria were as follow:

1. case reports, reviews, or letters;
2. the same data had been published repeatedly;
3. outcomes of interest did not be reported.

Two reviewers independently selected the potentially qualified studies according to the inclusion and exclusion criteria. Any disagreement was resolved by discussion and the conformity was reached.

2.4. Data extraction and management

Two reviewers extracted data independently. The data includes the following categories: study design, patients demographic data (sample size, age, and sex), duration of follow-up, clinical evaluation (JOA, ODI, and VAS), complications, fusion rates, hospital stay, incision length, blood loss, and operation time.

2.5. Quality assessment

As most included studies were non-randomized controlled studies, the Newcastle–Ottawa Scale was used to assess the quality of each study. This scale for non-randomized case controlled studies and cohort studies was used to allocate a maximum of nine points for the quality of selection, comparability, exposure, and outcomes for study participants.[29]

3. Statistical analysis

We calculated relative risk (RR) with 95% confidence interval (CI) for dichotomous outcomes and mean difference (MD) with 95% CI for continuous outcomes. P values less than .05 denoted significant differences. I^2 statistic was used to quantify heterogeneity, which I^2 greater than 50% implied significant heterogeneity. The random-effect model was used if there was significant heterogeneity. Otherwise, the fixed-effect model was used. Sensitivity analysis was conducted to examine the influence of excluding each study. Publication bias was assessed using Egger and Begg tests. The trim and fill method was used to estimate the number of studies that might have been missing and to adjust the pooled estimate. Review Manager 5.3 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark) and STATA 12.0 (Stata Corporation, College Station, TX) were used for the statistical analyses.

4. Results

4.1. Search results

A total of 345 records were identified through initial database search. Finally, 12 studies were included in this meta-analysis after removing duplicates and reviewing title/abstracts/full-text. The literature search procedure was shown in Figure 1.

4.2. Baseline characteristics and quality assessment

All 12 studies were published between 2015 and 2018. The number of patients in CBT and PS group ranged from 10 to 95 (total = 372) and 10 to 82 (total = 397) respectively. Characteristics of included studies were presented in Table 1.

As most studies included were non-randomized controlled studies (4 in prospective and 7 in retrospective), the Newcastle–Ottawa Scale was used to assess the quality of each study. Of these, 4 studies scored 8 points and 7 studies scored 9 points. Therefore, the quality of each study was high (Table 2).

4.3. Clinical evaluation

Preoperative and postoperative VAS (final follow-up) of lower back pain were analyzed in 6 studies (164 patients in CBT group and 168 patients in PS group). There was no significant difference between 2 groups in preoperative VAS [$P=.25$, MD $=0.14$ (-0.10, 0.38); heterogeneity: $P=0.51$, $I^2=0\%$, Fixed-effect model] (Fig. 2A) and in postoperative VAS [$P=0.32$, MD $=$ 0.41 (-0.40, 1.22); heterogeneity: $P<.01$, $I^2=94\%$, Random-effect model] (Fig. 2B).

Preoperative and postoperative VAS (final follow-up) of radiating pain were analyzed in three studies (73 patients in CBT group and 84 patients in PS group). There was no significant difference between 2 groups in preoperative VAS [$P=.59$, MD $=$ 0.13 (-0.35, 0.62); heterogeneity: $P=.96$, $I^2=0\%$, Fixed-effect model] (Fig. 2C) and in postoperative VAS [$P=.92$, MD $=-0.03$ (-0.51, 0.46); heterogeneity: $P<.01$, $I^2=85\%$, Random-effect model] (Fig. 2D).

Preoperative and postoperative JOA scores (final follow-up) were analyzed in 2 studies (111 patients in CBT group and 98 patients in PS group). There was no significant difference between 2 groups in preoperative JOA scores [$P=.27$, MD $=-3.25$ (-9.01, 2.51); heterogeneity: $P=.01$, $I^2=83\%$, Random-effect model] (Fig. 3A) and in postoperative JOA scores [$P=.07$, MD $=$ 0.87 (-0.06, 1.81); heterogeneity: $P=.51$, $I^2=0\%$, Fixed-effect model] (Fig. 3B).

Preoperative and postoperative ODI (final follow-up) were analyzed in 4 studies (124 patients in CBT group and 130 patients in PS group). There was no significant difference between 2 groups in preoperative ODI [$P=.11$, MD $=1.63$ (-0.39, 3.65); heterogeneity: $P=.34$, $I^2=10\%$, Fixed-effect model] (Fig. 3C) and in postoperative ODI [$P=.31$, MD $=-0.67$ (-1.98, 0.64); heterogeneity: $P=.79$, $I^2=0\%$, Fixed-effect model] (Fig. 3D).

4.4. Operation time and blood loss

Operation time and blood loss were analyzed in 9 studies (308 patients in CBT group and 335 patients in PS group). There was no significant difference between 2 groups in operation time

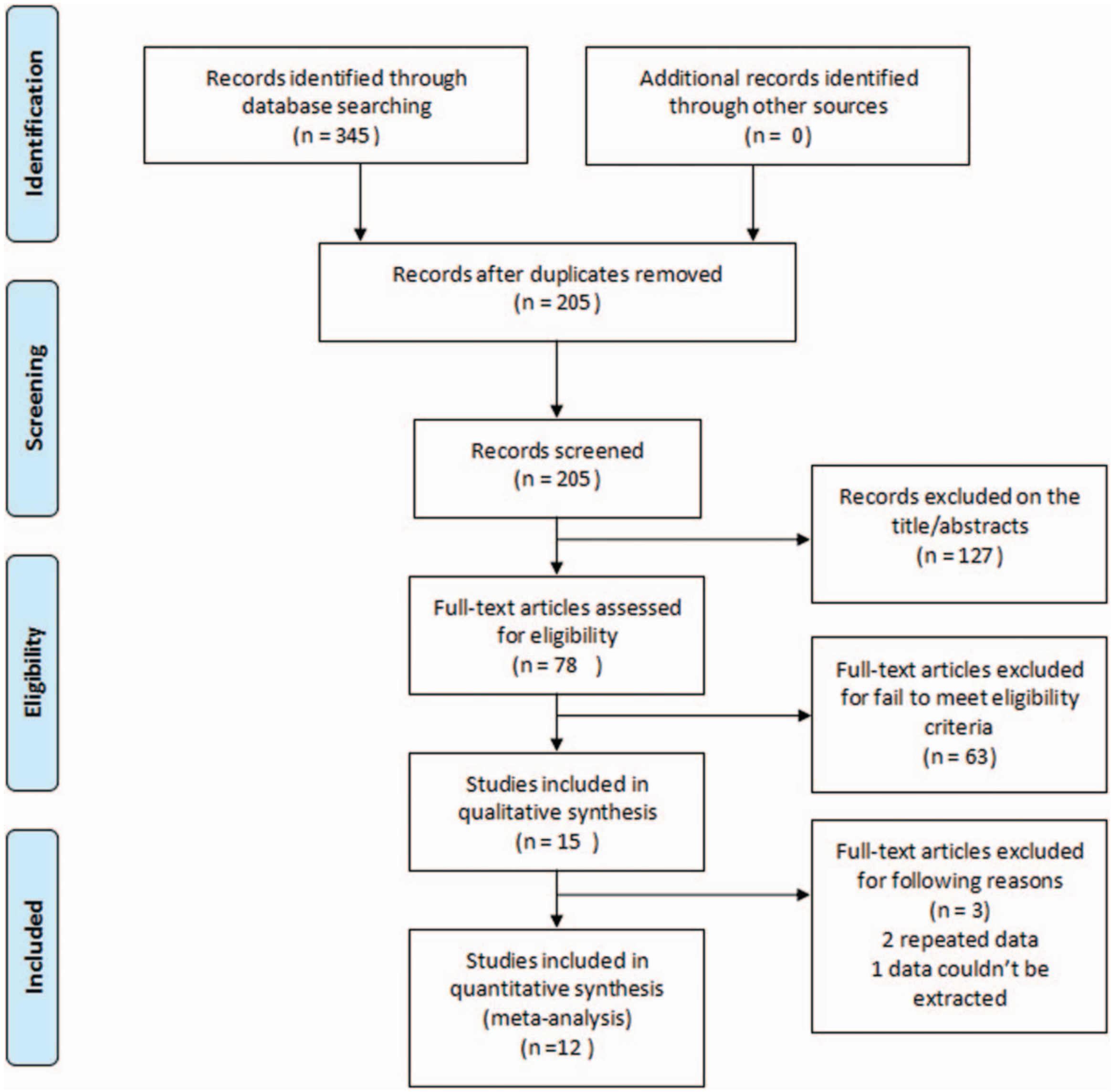

Figure 1. Flow diagram of study selection.

Table 1

Characteristics of included studies.

Study	Country	Design	No. of Patients CBT	No. of Patients PS	Mean Age (years) CBT	Mean Age (years) PS	No. of Males/Females CBT	No. of Males/Females PS	Mean Follow-Up (month)
Kasukawa et al[17]	Japan	retrospective	10	10	67	63	3/7	6/4	8/16
Orita et al[18]	Japan	prospective	20	20	63.5 ± 9.4	63.7 ± 14.3	11/9	12/8	12
Hung et al[11]	China	retrospective	16	16	60.37 ± 11.07	64.12 ± 5.79	6/10	5/11	18
Ninomiya et al[19]	Japan	retrospective	11	10	62.2 ± 2.5	61.4 ± 2.6	7/4	5/5	12
Sakaura et al[20]	Japan	prospective	95	82	68.7 ± 9.5	67.0 ± 8.7	46/49	36/46	35.4/40.2
Chen et al[21]	America	prospective	18	15	53.39 ± 1.97	59.20 ± 3.12	11/7	2/13	8
Chin et al[22]	America	prospective	30	30	48 ± 3	62 ± 3	18/12	15/15	24
Takenaka et al[23]	Japan	retrospective	42	77	65.8 ± 8.1	66.0 ± 11.2	18/24	31/46	12
Lee and Ahn[24]	Korea	RCT	35	37	51.2 ± 11.9	51.7 ± 10.4	31/4	33/4	24
Peng et al[26]	China	retrospective	51	46	62.8	61.9	23/28	21/25	12
Shi et al[27]	China	retrospective	22	23	73.3 ± 7.1	73.7 ± 7.0	13/9	13/10	23.1/24.3
Lee and Shin[28]	Korea	retrospective	22	31	62.7 ± 10.1	64.2 ± 9.3	9/13	12/19	12

CBT = cortical bone trajectory, PS = pedicle screw, RCT = randomized controlled trial.

Table 2

The quality assessment of non-randomized controlled studies according to the Newcastle–Ottawa Scale.

Study	Selection	Comparability	Exposure	Total score
Kasukawa et al[17]	4	2	3	9
Orita et al[18]	4	2	3	9
Hung et al[11]	4	2	2	8
Ninomiya et al[19]	4	2	3	9
Sakaura et al[20]	4	2	3	9
Chen et al[21]	4	2	3	9
Chin et al[22]	3	2	3	8
Takenaka et al[23]	4	2	3	9
Peng et al [26]	4	2	2	8
Shi et al[27]	4	2	2	8
Lee and Shin[28]	4	2	3	9

[P=.06, MD=−29.87 (−61.53, 1.78); heterogeneity: P<.01, I^2=98%, Random-effect model] (Fig. 4A). CBT group showed less blood loss [P<.01, MD=−113.03 (−176.11, −49.95); heterogeneity: P<.01, I^2=95%, Random-effect model] than PS group (Fig. 4B).

4.5. Hospital stay and incision length

Hospital stay was analyzed in 4 studies (111 patients in CBT group and 116 patients in PS group). CBT group showed less hospital stay [P<.01, MD=−1.67 (−2.82, −0.51); heterogeneity: P<.01, I^2=83%, Random-effect model] than PS group (Fig. 4C).

Incision length was analyzed in 2 studies (42 patients in CBT group and 51 patients in PS group). CBT group showed less incision length [P<.01, MD=−55.06 (−86.10, −24.03); heterogeneity: P<.01, I^2=95%, Random-effect model] than PS group (Fig. 4D).

4.6. Complications

Intraoperative complications were analyzed in 4 studies (198 patients in CBT group and 215 patients in PS group). There was

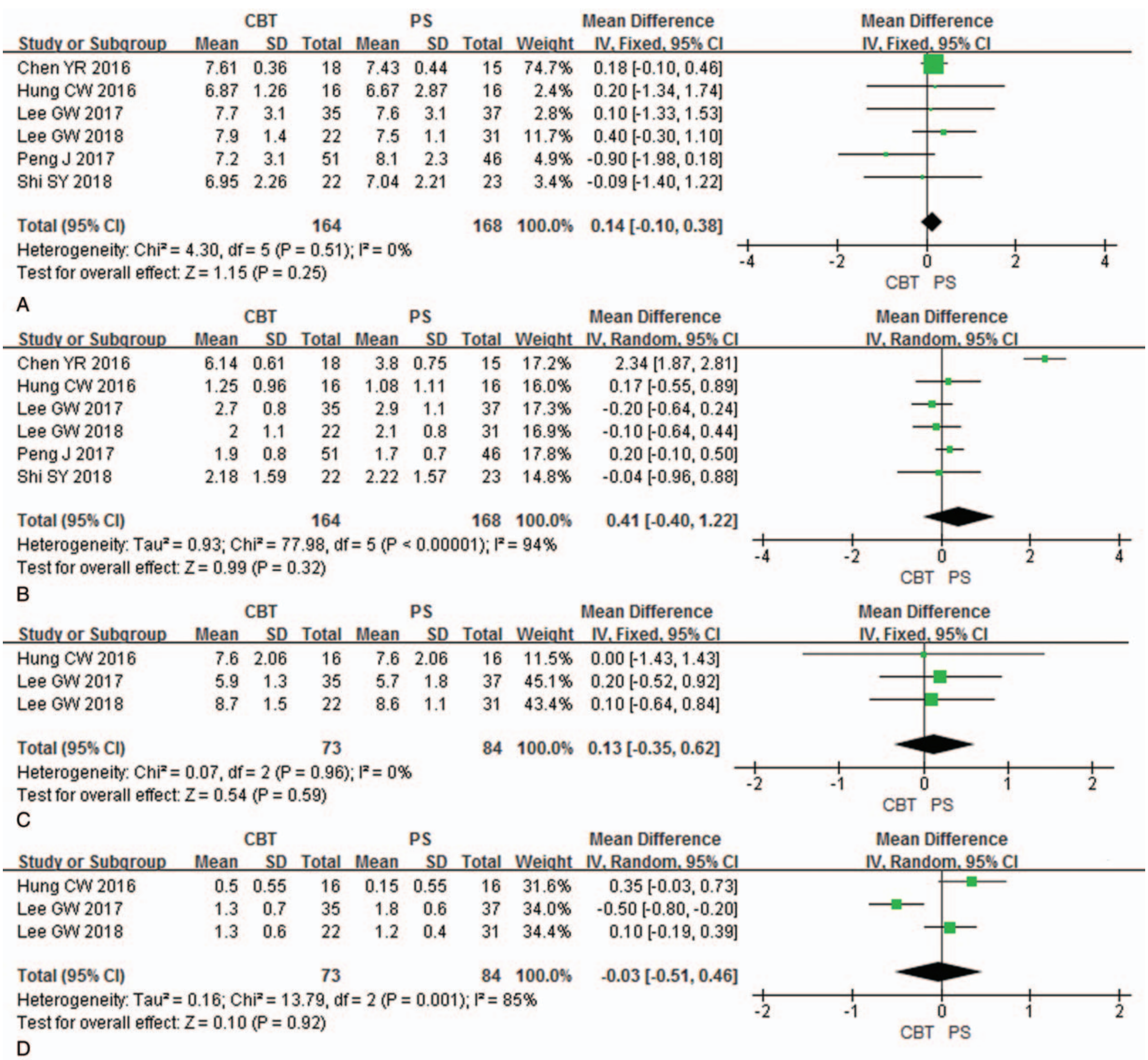

Figure 2. Forest plots of preoperative VAS of lower back pain (A), postoperative VAS of lower back pain (B), preoperative VAS of radiating pain (C), and postoperative VAS of radiating pain (D) in CBT group and PS group. CBT=cortical bone trajectory, PS=pedicle screw, VAS=visual analogue score.

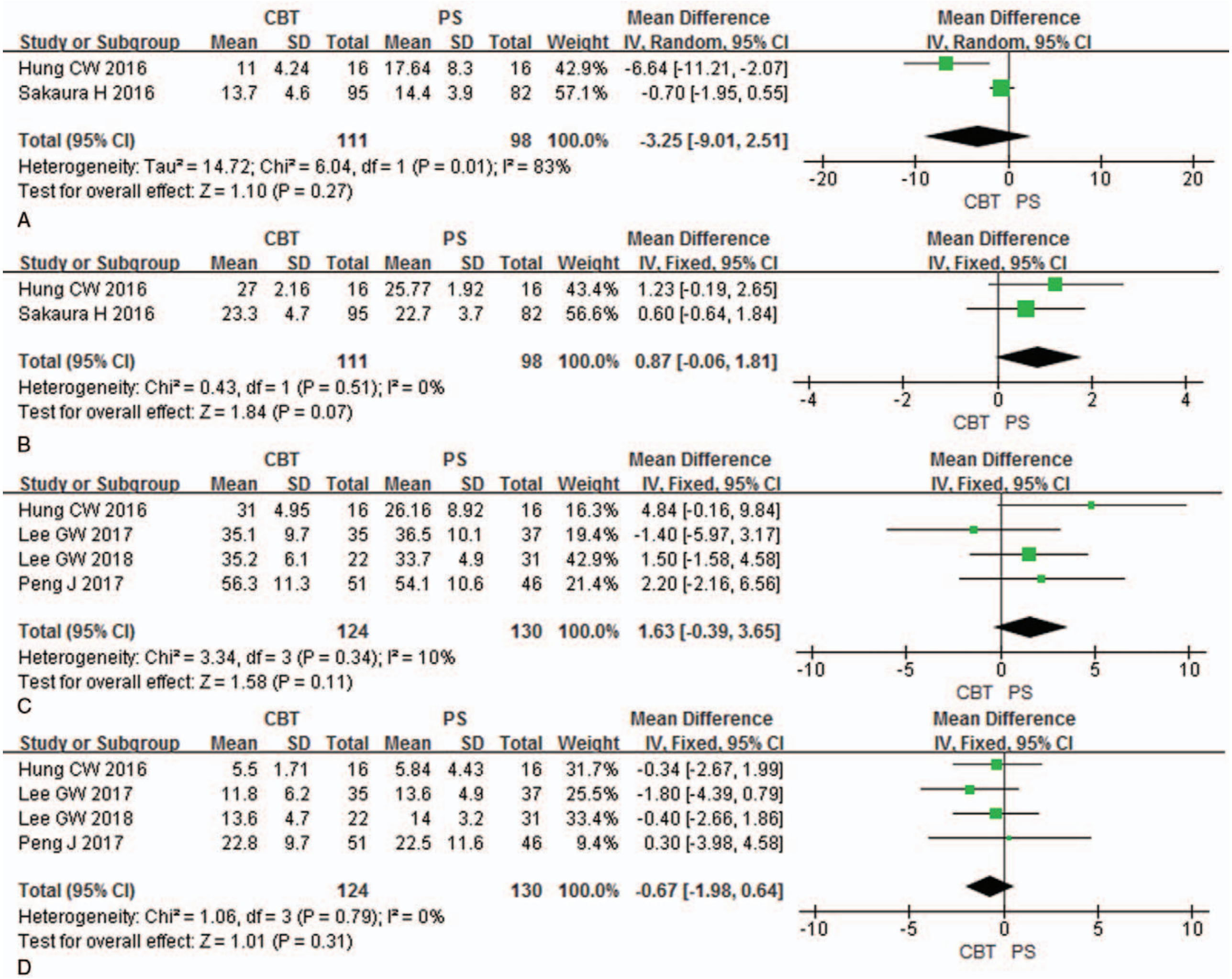

Figure 3. Forest plots of preoperative JOA (A), postoperative JOA (B), preoperative ODI (C) and postoperative ODI (D) in CBT group and PS group. CBT=cortical bone trajectory, JOA=Japanese Orthopedic Association, ODI=Oswestry disabilities index, PS=pedicle screw.

no significant difference between 2 groups in intraoperative complications [P=.49, RR=0.73 (0.31, 1.76); heterogeneity: P=.31, I^2=17%, Fixed-effect model] (Fig. 5A).

Postoperative complications were analyzed in 4 studies (223 patients in CBT group and 242 patients in PS group). There was no significant difference between 2 groups in postoperative complications [P=.07, RR=0.56 (0.29, 1.06); heterogeneity: P=.91, I^2=0%, Fixed-effect model] (Fig. 5B).

4.7. Fusion rates

Fusion rates were analyzed in 5 studies (245 patients in CBT group and 273 patients in PS group). There was no significant difference between 2 groups in fusion rates [P=.21, RR=0.97 (0.91, 1.02); heterogeneity: P=.71, I^2=0%, Fixed-effect model] (Fig. 5C).

5. Sensitivity analysis

To confirm the stability of the meta-analysis, sensitivity analysis was performed by sequentially omitting individual eligible studies.[29] The pooled results were not materially changed after any single study was excluded which indicated the stability of the results.

5.1. Publication bias

For 9 studies analyzed operation time, both Egger tests (P=.983) and Begg tests (P=.602) showed no publication bias (Fig. 6A). For 9 studies analyzed blood loss, both Egger tests (P=0.678) and Begg tests (P=.754) showed no publication bias (Fig. 6B). As included studies were few, publication bias was not assessed for other parameters.

6. Discussion

The key elements of screw fixation are pullout strength and stability. Biomechanical studies have demonstrated that CBT screw can provide a 30% increase in uniaxial yield pullout load than PS. In addition, the insertion torque of CBT screw is 1.71 times higher than that of PS.[9,12] However, whether or not CBT can provide similar clinical outcomes compared to PS has not yet been fully evaluated. Thus, we performed a meta-analysis to evaluate clinical results (JOA, ODI, and VAS), complications,

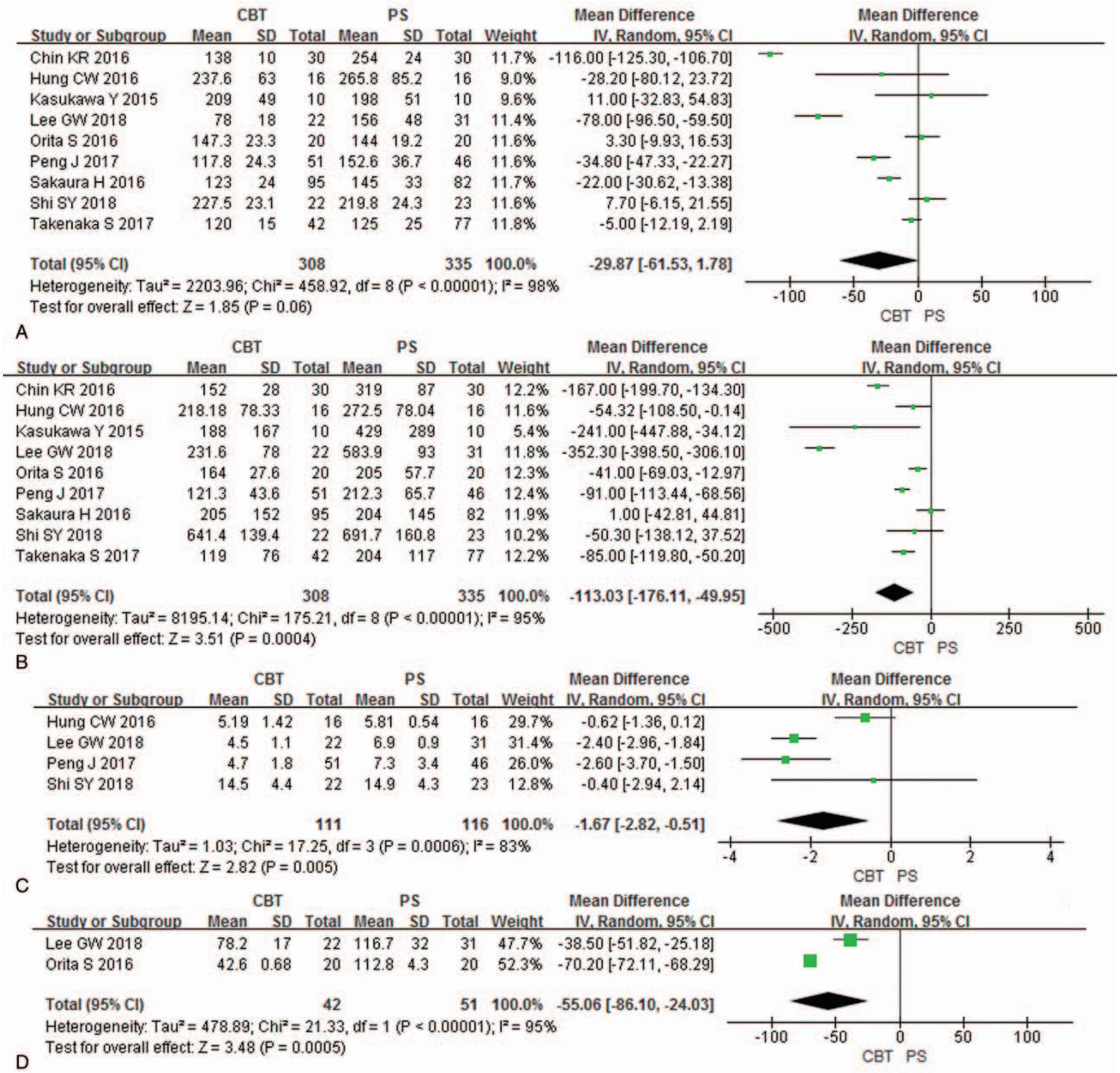

Figure 4. Forest plots of operation time (A), blood loss (B), hospital stay (C), and incision length (D) in CBT group and PS group. CBT = cortical bone trajectory, PS = pedicle screw.

fusion rates, hospital stay, incision length, blood loss, and operation time between 2 groups in lumbar fusion surgery.

This study suggests that there were no significant difference between two groups in VAS of lower back pain, VAS of radiating pain, JOA, ODI, intraoperative complications, postoperative complications, fusion rates, and operation time. However, CBT technique provided the additional benefits of less blood loss [$P < .01$], less hospital stay [$P < .01$], and less incision length [$P < .01$].

VAS, JOA, and ODI were often used to evaluate the improvement of clinical outcomes. The pooled data showed that there were no significant difference between the 2 groups in VAS, JOA, and ODI. Meanwhile, there were no significant differences between 2 groups in fusion rates. Intervertebral fusion and effective decompression were key points of lumbar fusion surgery. Strong internal fixation was the prerequisite for intervertebral fusion. Biomechanical studies have demonstrated that CBT screw can provide similar or better pullout strength and stability than PS.[12] Thus, both CBT and PS could provide well intervertebral fusion and satisfactory clinical outcomes.

Complications reported in the literature include intraoperative complications (dural tear, pedicle fracture, and misplacement) and postoperative complications (hematoma, wound infection, and adjacent segment disease). The pooled data showed that there were no significant differences between the 2 groups in intraoperative complications and postoperative complications. Sakaura et al demonstrated that the incidence of symptomatic adjacent segment disease was significantly higher in PS group than CBT group ($P < .05$).[20] Subgroup analysis was not possible due to the small number of included studies. So, further large-scale studies are needed in the future.

Operation time, blood loss, hospital stay, and incision length were important factors for assessing surgical trauma. The pooled

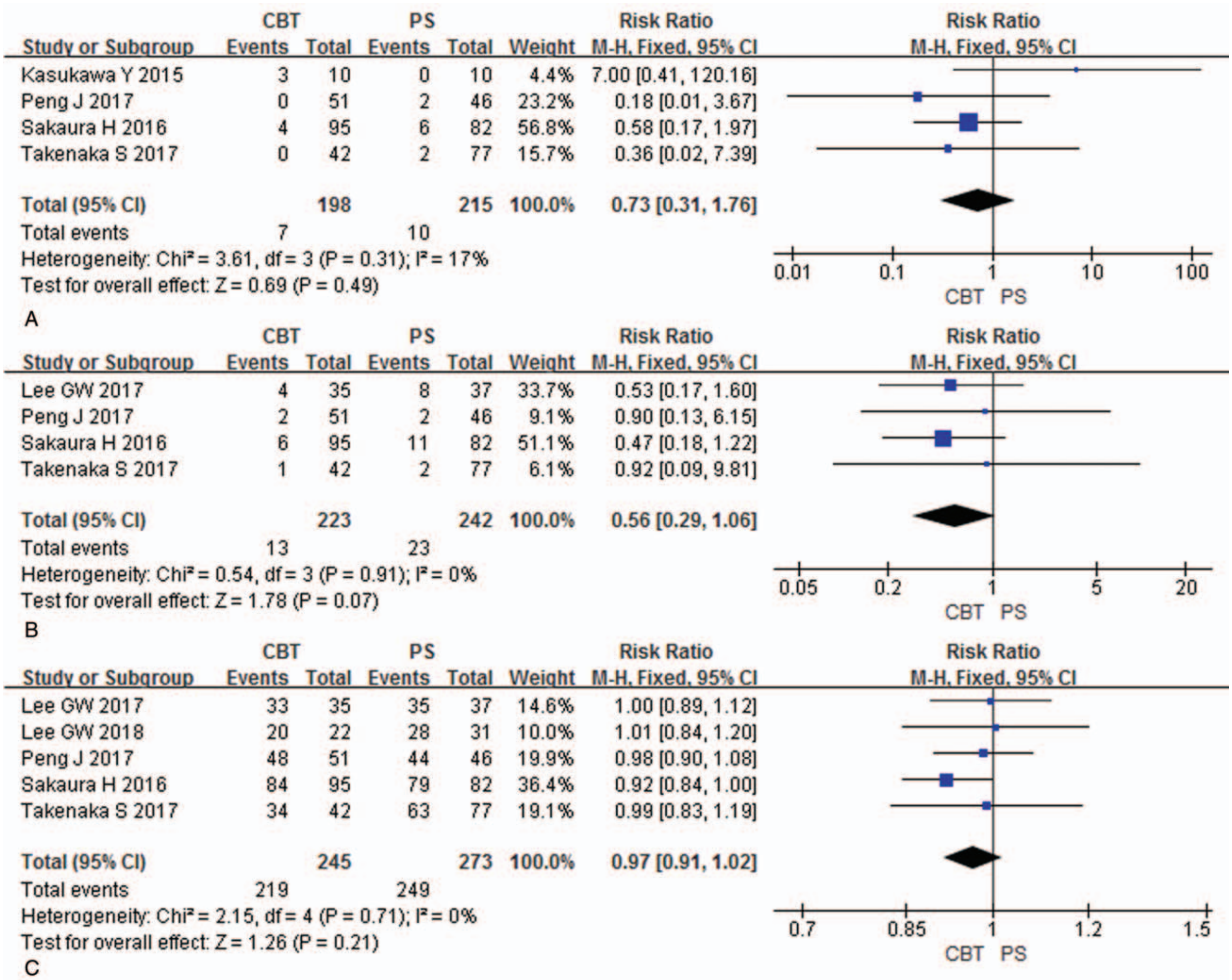

Figure 5. Forest plots of intraoperative complications (A), postoperative complications (B), and fusion rates (C) in CBT group and PS group. CBT = cortical bone trajectory, PS = pedicle screw.

data showed that CBT group with less blood loss, less hospital stay, and less incision length. As a novel technique, CBT has several advantages over PS. First, the insertion point of CBT is far from superior facet joint which may minimize the violation of superior facet joint.[4] Second, CBT has a medial starting point enables less muscle disruption and less tissue retraction which means less tissue trauma, less incision length, less blood loss, and less recovery time. For obese and morbid obese patients, the

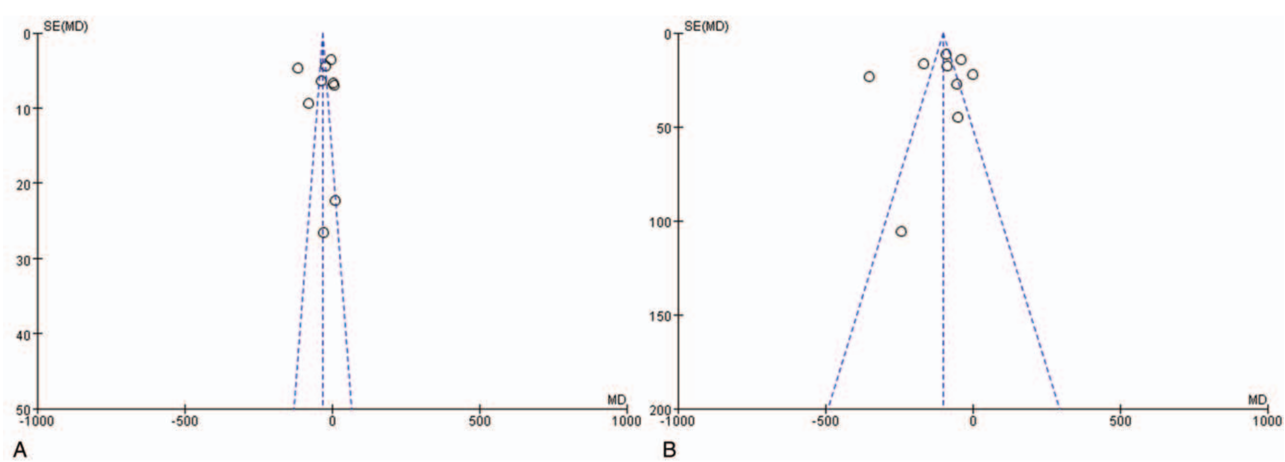

Figure 6. Funnel plots of operation time (A) and blood loss (B).

advantage will be more obvious.[5] Furthermore, its medial-to-lateral directed trajectory may also reduce risk of violation of pedicle medial wall and related dural injury.[10] Finally, CBT involves caudocephalad path and medial-to-lateral path with the objective of maximizing cortical bone contact through the pedicle to the vertebral body which can minimize the risk of instrumentation failure even in osteoporotic bone. So CBT screw may be applied to osteopenic or osteoporotic patients which may avoid the complications associated with bone cement.[13]

7. Study limitations

There are several limitations in this study. First, in all 12 included studies, only one study is randomized controlled trial and the other 11 included studies are non-randomized controlled studies (4 in prospective and 7 in retrospective). Second, the language of included studies was restricted to English. Third, follow-up times of included studies were different which may influence results.

8. Conclusions

CBT technique provided similar clinical outcomes (JOA, VAS, ODI), fusion rates, complications (intraoperative, postoperative), and operation time compared to PS technique in lumbar fusion surgery. However, CBT technique provided the additional benefits of less blood loss, less hospital stay, and less incision length.

Author contributions

Conceptualization: Yun-Zhi Ding.
Data curation: Jing-Nan Hu, Xiao-Feng Yang.
Formal analysis: Jing-Nan Hu.
Investigation: Jing-Nan Hu, Chuan-Ming Li.
Methodology: Chuan-Ming Li.
Software: Xin-Xin Li.
Validation: Xiao-Feng Yang, Xin-Xin Li.
Visualization: Xiao-Feng Yang, Xin-Xin Li.
Writing – original draft: Jing-Nan Hu, Xiao-Feng Yang.
Writing – review & editing: Xiao-Feng Yang, Yun-Zhi Ding.

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