Deformity Correction with Interbody Fusion Using Lateral versus Posterior Approach in Adult Degenerative Scoliosis: A Systematic Review and Observational Meta-analysis

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This study was designed to systematically review and meta-analyze the functional and radiological outcomes between lateral and posterior approaches in adult degenerative scoliosis (ADS). Both lateral (lumbar, extreme, and oblique) and posterior interbody fusion (posterior lumbar and transforaminal) are used for deformity correction in patients with ADS with unclear comparison in this cohort of patients in the existing literature. A literature search using three electronic databases was performed to identify studies that reported outcomes of lateral (group L) and posterior interbody fusion (group P) in patients with ADS with curves of 10°–40°. Group P was further subdivided into minimally invasive surgery (MIS-P) and open posterior (Op-P) subgroups. Data on functional, radiological, and operative outcomes, length of hospital stay (LOHS), fusion rates, and complications were extracted and meta-analyzed using the random-effects model. A total of 18 studies (732 patients) met the inclusion criteria. No significant difference was found in functional and radiological outcomes between the two groups on data pooling. Total operative time in the MIS-P subgroup was less than that of group L (233.86 minutes vs. 401 minutes, $p<0.05$). The total blood loss in group L was less than that in the Op-P subgroup(477 mL vs. 1,325.6 mL, $p<0.05$). Group L had significantly less LOHS than the Op-P subgroup (4.15 days vs. 13.5 days, $p<0.05$). No significant difference was seen in fusion rates, but complications were seen except for transient sensorimotor weakness (group L: 24.3%, group P: 5.6%; $p<0.05$). Complications, such as postoperative thigh pain (7.7%), visceral injuries (2%), and retrograde ejaculation (3.7%), were seen only in group L while adjacent segment degeneration was seen only in group P (8.6%). Lateral approach has an advantage in blood loss and LOHS over the Op-P subgroup. The MIS-P subgroup has less operative time than group L, but with comparable blood loss and LOHS. No significant difference was found in functional, radiological, fusion rates, pseudoarthrosis, and complications, except for transient sensorimotor deficits. Few complications were approach-specific in each group.

Keywords: Lumbar osteoarthritis; Scoliosis; Spinal fusion; Pedicle screws; Meta-analysis

Introduction

Adult degenerative scoliosis (ADS) or *de novo* scoliosis is a spinal coronal deviation of over 10° and is prevalent in the elderly population [1]. The prevalence of ADS is estimated from 13% in <60 years of age to 36% in >60 years

of age [2]. Patients present with a spectrum of neurological symptoms, including back pain, neurogenic claudication, radiculopathy, and generalized imbalance. Surgery is warranted when conservative treatment fails in providing relief to patients. The surgery mainly aimed for adequate decompression, stabilization, and restoration of both spinal coronal and sagittal alignment [3]. Interbody fusions have become increasingly popular due to their ability to restore the disc and foraminal height, thereby achieving indirect decompression, good fusion, lordosis restoration, and deformity correction [4]. Interbody fusion with a traditional posterior approach, such as posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF), has been proven successful in ADS; however, iatrogenic muscle trauma, nerve root injury, and dural tear are few posterior approach complications [4,5].

Lateral lumbar interbody fusion (LLIF), extreme lateral interbody fusion (XLIF), and oblique lateral interbody fusion (OLIF) are new techniques performed from the lateral approach, which works on the principle of indirect decompression by increasing the foraminal height. The lateral approach is gaining popularity because of minimal trauma to muscles, large surface area for fusion, large size cages, and fusion segment saving [4]. However, the potential risk of damage to the psoas muscle, lumbosacral plexus, bowel injury, vascular injury, changing the position to prone for instrumentation, and difficult access to L5–S1 disc space need to be considered before selecting the lateral approach [4,6]. Still, no definite evidence is available regarding the superiority of one approach over another in patients with ADS in the existing literature. The authors aim to systematically review and analyze the existing literature regarding the safety and efficacy of interbody fusion from posterior and lateral approaches in ADS.

Materials and Methods

1. Literature search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to conduct this systematic review [7]. An electronic literature search using PubMed, EMBASE, and Scopus databases was independently performed by two authors (S.M. and P.V.S.), from their dates of inception to May 20, 2021. The search aimed to identify the studies about the outcomes after deformity correction with interbody fusion performed from posterior or lateral approaches in patients with ADS. Both medical subject headings (MeSH) and non-MeSH/free text words for PICO (patient, intervention, comparator, and outcomes) framework were combined using the Boolean operators "AND" and "OR" to maximize the search sensitivity (Supplement 1). The search strategy was created by the first author (S.M.) and critically reviewed by all authors, and any discrepancies were resolved after discussion [8]. The references of all relevant studies were manually checked to include any additional studies. Duplicates were removed using Zotero citation manager software (https://www.zotero.org/) [9]. After a screening of titles and abstracts, full-text articles of potentially relevant studies were included.

2. Study selection criteria

The following are the inclusion criteria for the studies: (1) full-text articles published in English; (2) randomized controlled trials (RCT) or observational or cross-sectional study design; (3) adult cohort of >40 years of age, either sex, with primary or *de novo* ADS; (4) minimum of 10 patients; (5) mild to moderate curves with mean coronal Cobb's of 10°–40°; (6) surgical procedure involving interbody fusion with lateral approach (LLIF, XLIF, and OLIF) or posterior approach (PLIF and TLIF); (7) open or minimally invasive surgery (MIS); (8) clinical outcome reported as Visual Analog Scale (VAS) or Oswestry Disability Index (ODI); and (9) minimum follow-up duration of 12 months.

The following are the exclusion criteria: (1) non-English articles, without full-text; (2) case reports, review articles, systematic reviews, experimental studies, biomechanical studies, and conference abstracts; (3) patients with age of <40 years; (4) idiopathic, secondary adult, and syndromic or iatrogenic scoliosis; (5) heterogeneous cohort of patients operated for degenerative disc disease or spondylolisthesis alone without any deformity; (6) severe curves requiring osteotomy or circumferential fusion; (7) surgical procedure involving decompression alone or interbody fusion with anterior approach (anterior lumbar interbody fusion, ALIF) as a primary procedure; and (8) clinical outcomes reported other than VAS and ODI.

3. Quality assessment

Critical appraisal of the selected studies was independently performed by two reviewers (S.M. and P.V.S.)

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using the National Institutes of Health (NIH) quality assessment tool that uses 12 objective criteria regarding study objectives, selection criteria, eligibility, representativeness of study participants, sample size, intervention, outcome measures, blinding, statistical analysis, outcome assessment, lost to follow-up, and group level assessment [10]. Criteria are rated as good, fair, or poor. We gave a maximum of 1 point for each criterion (0: poor, 0.5: fair, 1: good) with a total maximum NIH score of 12. Studies with >50% NIH scores were considered of good quality and were included in the quantitative analysis.

4. Data extraction

All data were extracted using text, tables, figures, and any supplementary material. Two authors (S.M. and P.V.S.) independently extracted the data from the selected articles, and any discrepancies were resolved after discussion with the senior authors (P.K. and B.S.). Data of each surgical procedure was separately extracted in the case of studies comparing the difference between two surgical procedures. Studies were divided into two groups as follows: group L (lateral approach, including LLIF/XLIF/OLIF) and group P (posterior approach, including PLIF and TLIF). Group P was further divided into two subgroups, the open posterior (Op-P) and MIS-posterior subgroups (MIS-P). The baseline characteristics included the first author's name, country, year of publication, study design, sample size, gender, inclusion criteria, type of surgery, and duration of follow-up. The primary outcome included functional outcome reported as a change in VAS or ODI or both. Secondary outcome measures included the following: (1) radiographic outcomes, such as changes in Cobb's angle, lumbar lordosis (LL), and sagittal vertical axis (SVA); (2) operative time and blood loss; (3) fusion rate; (4) length of hospital stay (LOHS); and (5) complications.

5. Statistical analysis

All statistical analyses were performed using Metafor package in R statistical software ver. 4.0.0 (The R Foundation for Statistical Computing, Vienna, Austria; 2020) [11]. Descriptive characteristics of pooled data were expressed as mean and standard deviation (SD) for continuous data and as percentages and proportions for categorical data. Forest plots were used to show the comparison between the groups. DerSimonian and Laird's random-effects

model was used when heterogeneity was high, otherwise fixed-effects model was used. The Higgins I^2 test was used to assess the heterogeneity among the studies [12]. Standardized mean difference (SMD), 95% confidence intervals (CI), and probability values were used for the comparison of continuous data. Relative risk and 95% CI were used to analyze categorical or binary data. All p-values of <0.05 and no overlap within 95% CI was considered a statistically significant difference. Funnels plots were used to assess the publication bias by visual inspection of plots and Egger's regression test [13].

Results

1. Study selection

The literature search used PubMed, Google Scholar, and Scopus and identified 288 articles. From selected articles, 158 additional records were identified [14-16]. A total of 182 articles were left after removing duplicates. Following initial screening of titles and abstracts, only 63 full-text articles in English were considered potentially eligible. After excluding 45 articles due to inadequate sample size (n=3), inadequate follow-up (n=3), review articles/case reports (n=10), outcome measures other than VAS/ODI (n=11), missing data like SD values (n=5), a heterogeneous cohort of patients (n=8), severe curves (n=2), and osteotomy/ALIF as a primary procedure (n=3), only 18 articles met the inclusion criteria and were included in quantitative analysis [17-34]. Fig. 1 shows the flow diagram of the study as per PRISMA protocol.

2. Study characteristics (Table 1)

A total of 18 studies (732 patients) were included in the quantitative analysis. Most of the studies were retrospective (n=15) while only three were prospective [18,28,32]. The mean age of the patients was 67.2±3.53 years. Out of the 732 patients, 515 were females while 217 were males. Follow-up period ranged from 12 to 156 months with a mean of 30.2 months. Out of 18 studies, eight belonged to group L (267 patients) and 10 belonged to group P (465 patients). In group L, interbody procedures included LLIF/XLIF in six studies and OLIF in two studies. In group P, four studies were MIS-TLIF while six were open posterior surgeries (O-TLIF and O-PLIF, three studies each). On NIH quality assessment, all studies were found

Table 1. Study characteristics

Author	Year	Country	Study period	Study design	No. of patients	Mean age (yr)	Sex (M/F)	Inclusion criteria	Open/MIS	Interbody fusion	Adjunct	No. of levels of interbody/total (mean±SD)	FU (mo)
Wang et al. [17]	2010	USA	NS	Retrospective	23	64.4 (range, 42–84)	6/17	ADS (coronal Cobbs >20° and/or loss of global sagittal balance)	MIS	LLIF	BMP-2	86 (3.7±1.25)	13.4
Philips et al. [18]	2013	USA	NS	Prospective	107	68 (range, 45–87)	29/78	ADS (between T8 and S1; age >45 yr; scoliosis >10; ODI >30)	MIS	XLIF		344 (3.2±2.5)	Minimum 24
Khajavi et al. [19]	2014	USA	2005–2009	Retrospective	21	70.1 (range, 48–79)	7/14	ADS	MIS	XLIF	BMP-2	70 (3.3±2)	24 (range, 12–36)
Baghdadi et al. [20]	2014	USA	1997–2011	Retrospective matched cohort	33	66	7/26	DLS	MIS	LLIF		181 (5±2)	21.6
Kim et al. [21]	2018	South Korea	2013–2016	Retrospective	32	68 (range, 58–78)	4/28	ADS (degenerative scoliosis; degenerative kyphoscoliosis)	MIS	OLIF		122 (3.8±1)	26.1±6.2
Takatori et al. [22]	2018	Japan	NS	Retrospective	12	72 (range, 65–76)	0/12	ADS (type 1 adult scoliosis)	NS	XLIF		34 (2.8±1.2)	18.24
Katz et al. [23]	2019	USA	2012–2016	Retrospective	27	66	10/17	ADS (LLIF ≥3 levels; preoperative coronal Cobb angle ≥10°)	MIS	LLIF	Allograft DBM or synthetic BGS mixed with bone marrow aspirate	100 (3.7±1)	23±12
Yang et al. [24]	2021	China	Jul 2017–Dec 2018	Retrospective	12	67.2	2/10	DLS (coronal Cobb angle of >10° or SVA >5 cm; Silva and Lenke types 2–4)	MIS	OLIF	Allogenic bone graft	34 (2.8±0.5)	26.8±1.8
Wu et al. [25]	2008	Taiwan	Apr 2000–Apr 2004	Retrospective	26	64.2	11/15	DLS (failed conservative management)	Open	PLIF		83 (2.4±0.7)	36 (range, 24–72)
Tsai et al. [26]	2011	Taiwan	May 2004–Jan 2007	Retrospective	58	68.9	11/47	DLS (coronal Cobbs >10°, age >50 yr; refractory to medical treatment, minimal 2-yr FU)	Open	PLIF		(2.8±1.0)	38.7±11.0
Sabou et al. [27]	2019	UK	2009–2015	Retrospective	64	70.26 (range, 49–90)	13/51	DLS (coronal Cobbs >20°, PI–LL >11°, PT >25°)	Open	PLIF		209 (3.2±0.75)	64 (range, 36–108)
Scheufler et al. [28]	2010	Germany	Jul 2006–Oct 2008	Prospective	30	73.2 (range, 64–88)	12/18	DLS (Cobbs >25°; back pain; progressive lumbar radiculopathy)	MIS	TLIF	BMP-2, prophylactic cement augmentation in 10 patients	134 (4.46±0)	19.6 (range, 10–32)
Wang et al. [29]	2013	USA	NS	Retrospective	25	72 (range, 62–84)	8/17	ADS (Cobbs >20°; failed conservative)	MIS	TLIF	BMP-2	80 (3.2±0.76)	Minimum 12
Du et al. [30]	2017	China	Jan 2012–Nov 2014	Retrospective	96	63.9	43/53	ADS (DLS with neurological symptoms; without central LCS)	Robot-assisted MIS	TLIF	Gelatin sponge impregnated with a mixture of 3 drugs to intraoperative nerve root block	130 (1.4±0.5)	16.4 (range, 13–24)
Zhao et al. [31]	2018	China	Jan 2008–Jan 2014	Retrospective	22	63.7	8/14	DLS (Cobbs >10°, one level lumbar stenosis; refractory to medical management)	MIS	TLIF		22 (1±0)	24

Table 1. Continued

Author	Year	Country	Study period	Study design	No. of patients	Mean age (yr)	Sex (M/F)	Inclusion criteria	Open/MIS	Interbody fusion	Adjunct	No. of levels of interbody/total (mean±SD)	FU (mo)
Crandall et al.[b] [32]	2009	USA	NS	Prospective non-randomized	20	67 (range, 49–81)	2/18	ADS (progressive deformity/spinal imbalance/failed conservative management 12 months)	Open	TLIF	BMP-2	54 (2.7±0.75)	31 (range, 24–42)
Burniekiene et al. [33]	2012	USA	Feb 2003–Oct 2009	Retrospective	29	65.9 (range, 49–83)	7/22	DLS (DLS with neurogenic claudication and painful lumbar degenerative disc disease; refractory to conservative management)	Open	TLIF		37 (2.2±0.75)	30 (range, 15–47)
Zhu et al. [34]	2014	China	Jan 1999–Dec 2007	Retrospective	95	58.5	37/58	DLS (age >50 yr, coronal Cobbs >25°, minimal 5-yr FU)	Open	TLIF		236 (2.8±1.0)	93.6 (range, 60–156)

M, male; F, female; MIS, minimally invasive surgery; SD, standard deviation; FU, follow-up; NS, not specified; ADS, adult degenerative scoliosis; LLIF, lateral lumbar interbody fusion; BMP, bone morphogenic protein; ODI, Oswestry Disability Index; XLIF, extreme lateral interbody fusion; DLS, degenerative lumbar scoliosis; OLIF, oblique lumbar interbody fusion; DBM, demineralized bone matrix; BGS, bone graft substitutes; SVA, sagittal vertical axis; PLIF, posterior lumbar interbody fusion; PI, pelvic incidence; LL, lumbar lordosis; PT, pelvic tilt; TLIF, transforaminal lumbar interbody fusion; LCS, lumbar canal stenosis.
a)Only LLIF group patients included. b)Only TLIF group patients included.

of good quality with a mean score of 10.27, ranging from 9 to 11.5 (Supplement 2).

3. Functional outcomes (Table 2)

1) Visual Analog Scale back (Fig. 2)
A total of 17 studies reported the pre- and post-intervention VAS scores for back pain. Eight and nine studies showed an SMD of −3.88 (95% CI, −4.67 to −3.09; I^2=89.53%). and −4.41 (95% CI, −5.26 to −3.55; I^2=95.03%) in groups L and P, respectively. Negative SMD shows VAS improvement after the intervention in both groups. The difference in subgroups was not significant (overlapping CI).

2) Visual Analog Scale leg (Fig. 3)
A total of 12 studies reported the pre- and post-intervention VAS scores for leg pain. Eight and four studies showed an SMD of −3.26 (95% CI, −4.25 to −2.26; I^2=90.81%) and −4.7 (95% CI, −6.17 to −3.23; I^2=95.01%) in groups L and P, respectively. All studies showed improvement in VAS scores postoperatively. The difference in subgroups was not significant.

3) Oswestry Disability Index (Fig. 4)
A total of 12 studies reported the ODI score pre- and post-intervention. Four and nine studies showed an SMD of −21.28 (95% CI, −26.4 to −16.16; I^2=90.29%) and −27.97 (95% CI, −36.84 to −19.09; I^2=97.78%) in groups L and P, respectively. Negative SMD shows improvement in ODI postoperatively in both groups. The difference in subgroups was not significant.

4. Radiographic outcomes (Table 2)

1) Cobb's angle (Fig. 5)
A total of 18 studies reported the pre- and post-intervention Cobb's angle. Eight and 10 studies showed an SMD of −13.66 (95% CI, −16.64 to −10.68; I^2=83.56%). and −17.46 (95% CI, −21.53 to −13.38; I^2=93.73%) in groups L and, respectively. All studies showed a decreased Cobbs' angle postoperatively. Subgroup difference was not significant.

2) Lumbar lordosis (Fig. 6)
A total of 17 studies reported the pre- and post-intervention LL angle. Seven and 10 studies showed an SMD of 15.6 (95% CI, 6.57 to 24.63; I^2=95.82%) and 11.46 (95% CI, 5.6 to 17.32; I^2=94.5%) in groups L and P, respectively. All

Table 2. Clinical and radiographic outcomes

Author	VAS back			VAS leg			ODI			Cobbs (°)			LL (°)			SVA (cm)		
	Preop	Postop	Change	Preop	Postop	Change	Preop	Postop	Change	Preop	Postop	Change	Preop	Postop	Change	Preop	Postop	Change
Wang et al. [17]	7.3±1.9	3.35±2.01	-3.95±2.76	4.35±2.9	1.57±1.7	-2.78±3.36	-	-	-	31.4±13.37	11.4±9.2	-20±16.23	37.7±8.5	45.5±6.9	7.8±10.9	-	-	-
Philips et al. [18]	-	-	-3.4±3.1	-	-	-3.5±3.9	-	-	-	20.9±10.4	15.2±10.6	-5.7±14.85	-	-	-	-	-	-
Khajavi et al. [19]	7±1.5	2.9±2.17	-4.1±2.63	5.6±2.8	3.3±2.17	-2.3±3.54	48.4±14.3	24.4±15.6	-24±21.16	27.6±7.9	16.6±1068	-11±13.28	31.8±13.5	44±12.07	12.2±18.1	-	-	-
Baghdadi et al. [20]	8±2	2±3	-6±3.6	4±4	1.5±3	-2.5±5	-	-	-	39±18	16±11	-23±21.09	38±14	44±14	6±19.79	4.9±4.7	3.8±3.2	-1.1±5.68
Kim et al. [21]	5.6±1	2±0.7	-3.6±1.2	5.1±2.6	1.5±1.1	-3.6±1.94	55.4±16	22.6±5.8	-32.8±17.01	21.55±6.97	9.6±4.9	-11.95±8.52	5.79±16.04	46.54±6.11	40.75±17.12	13.66±6.32	2.94±2.63	-10.72±6.84
Takatori et al. [22]	7.1±2.2	4.7±2.2	-2.4±3.1	5.7±3.7	4.2±1.6	-1.5±4.03	-	-	-	30.0±12.2	9.8±4.5	-20.2±13	8.1±27.0	39.8±15.8	31.7±31.28	12.3±4.7	4.3±3.8	-8±6.04
Katz et al. [23]	6±0.7	3.57±0.86	-2.44±1.13	5.86±0.49	3.12±0.8	-2.74±0.93	41.5±2.29	25.68±4.86	-15.82±5.37	22.1±1.99	8.7±1.08	-13.3±2.26	47.3±2.06	52.7±2.14	5.4±2.97	-	-	-
Yang et al. [24]	7.3±0.9	2.1±0.8	-5.2±1.2	7.8±0.9	1.8±0.8	-6±1.2	38.8±2.3	21.9±2	-16.9±3.04	19.6±4.8	6.9±3.8	-12.7±6.12	29.4±8.6	40.8±5.8	11.4±10.37	4.3±4.3	1.5±1	-2.8±4.4
Wu et al. [25]	-	-	-	-	-	-	58±11.5	25.8±19	-32.2±22.2	16.5±5.7	7.4±3.4	-9.1±6.63	22.2±15.7	30.1±13.3	7.9±20.57	-	-	-
Tsai et al. [26]	7.4±2	2.4±2	-5±2.8	-	-	-	28.1±8	12.2±8.8	-15.9±11.89	19.3±6.8	7.7±5.4	-11.6±8.68	30.0±13.7	29.0±9.5	-1±16.67	-0.33±3.4	-0.42±2.72	-0.09±4.35
Sabou et al. [27]	7.5±2.25	3.7±2.8	-3.7±3.59	6.5±3.75	3.75±3.2	-2.75±4.93	-	-	-	30.34±13.88	7.98±7.08	-22.36±15.58	28.05±18.21	43.8±10.46	15.75±21	6.08±5.68	4.96±3.82	-1.12±6.84
Scheufler et al. [28]	7.5±0.8	2.68±0.76	-4.82±1.1	-	-	-	57.2±6.9	25.5±5.3	-31.7±8.7	42±13.32	10.3±7.8	-31.7±15.43	8.8±8.9	36±6.9	27.2±11.26	3.16±1.52	0.8±0.84	-2.36±1.73
Wang et al. [29]	7.6±1.7	3.4±1.7	-4.2±2.4	5.1±2.02	1.8±0.99	-3.3±2.25	44.9±11.8	24.1±11.6	-20.8±16.54	29.2±9.3	9.0±5.0	-20.2±10.55	27.8±12.9	42.6±12.1	14.8±17.68	7.4±4.9	4.3±5.7	-3.1±7.51
Du et al. [30]	6.54±1.17	2.9±0.4	-3.64±1.23	7.13±1.35	1.48±0.27	-5.65±1.37	58.2±11.3	12.9±4.4	-45.3±12.12	33.7±10.2	16.6±4.4	-17.1±11.1	44.6±9.2	61.4±9.8	16.8±13.44	4.80±0.61	1.73±0.51	-3.07±0.78
Zhao et al. [31]	6.2±1.8	2.2±0.7	-4±1.93	8.2±0.7	1.4±1.4	-6.8±1.56	62.4±16.1	24.2±9.3	-38.2±18.59	20.7±7	12.7±7.1	-8±9.97	39.5±13.6	43.6±10.6	4.1±17.24	-	-	-
Crandall et al. [32]	6.75±1.75	3.59±2	-3.16±2.65	-	-	-	46.5±12.5	27.9±12.2	-18.6±17.46	23.95±13.5	7.5±3.75	-16.4±14	44.8±13.2	48.4±4	3.6±13.79	-	-	-
Bumiekiene et al. [33]	7.6±1.5	3.6±2	-4±2.5	-	-	-	-	-	-	32.3±10	15.4±12	-16.8±15.62	37.6±9.75	40.5±8.3	2.9±12.8	-	-	-
Zhu et al. [34]	8.9±2	2±1.2	-6.9±2.3	-	-	-	32.2±8.6	11.1±6.8	-21.1±10.96	31.1±10.3	8.3±3.6	-22.8±10.9	9.3±7.6	30.1±9.5	20.8±12.16	-	-	-

Values are presented as mean±standard deviation.
VAS, Visual Analog Scale; ODI, Oswestry Disability Index; LL, lumbar lordosis; SVA, sagittal vertical axis; Preop, preoperative; Postop, postoperative.
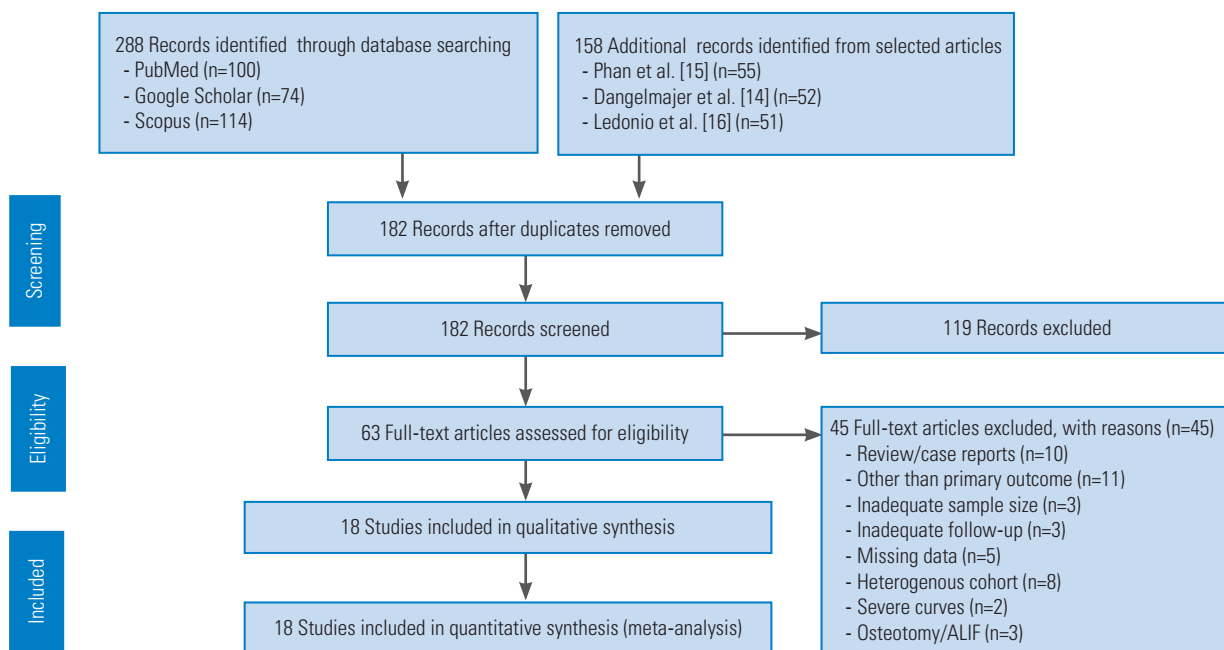
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Fig. 1. Flow diagram of the study as per PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. ALIF, anterior lumbar interbody fusion.
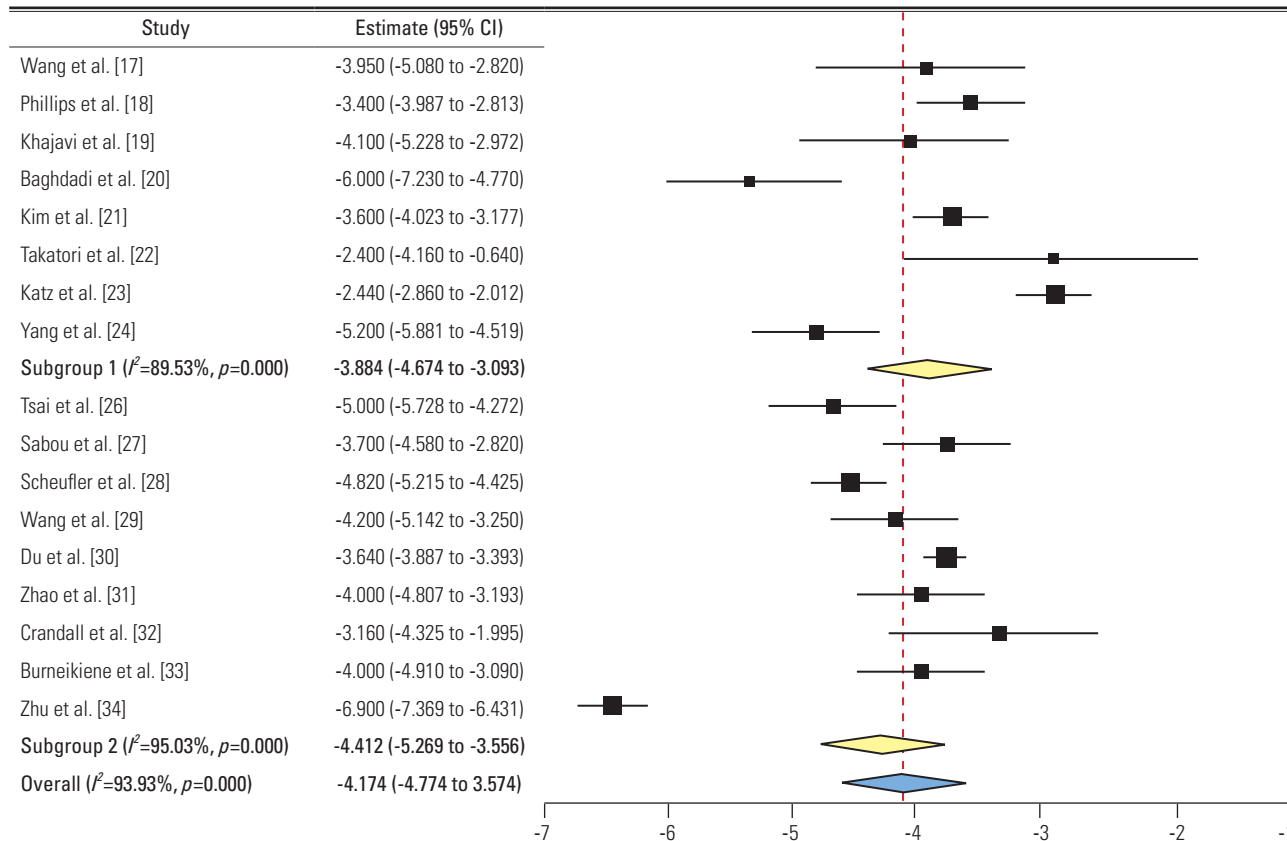
VAS back

Study	Estimate (95% CI)
Wang et al. [17]	-3.950 (-5.080 to -2.820)
Phillips et al. [18]	-3.400 (-3.987 to -2.813)
Khajavi et al. [19]	-4.100 (-5.228 to -2.972)
Baghdadi et al. [20]	-6.000 (-7.230 to -4.770)
Kim et al. [21]	-3.600 (-4.023 to -3.177)
Takatori et al. [22]	-2.400 (-4.160 to -0.640)
Katz et al. [23]	-2.440 (-2.860 to -2.012)
Yang et al. [24]	-5.200 (-5.881 to -4.519)
Subgroup 1 (I^2=89.53%, p=0.000)	-3.884 (-4.674 to -3.093)
Tsai et al. [26]	-5.000 (-5.728 to -4.272)
Sabou et al. [27]	-3.700 (-4.580 to -2.820)
Scheufler et al. [28]	-4.820 (-5.215 to -4.425)
Wang et al. [29]	-4.200 (-5.142 to -3.250)
Du et al. [30]	-3.640 (-3.887 to -3.393)
Zhao et al. [31]	-4.000 (-4.807 to -3.193)
Crandall et al. [32]	-3.160 (-4.325 to -1.995)
Burneikiene et al. [33]	-4.000 (-4.910 to -3.090)
Zhu et al. [34]	-6.900 (-7.369 to -6.431)
Subgroup 2 (I^2=95.03%, p=0.000)	-4.412 (-5.269 to -3.556)
Overall (I^2=93.93%, p=0.000)	-4.174 (-4.774 to 3.574)

Fig. 2. Forest plot showing Visual Analog Scale (VAS) back (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.
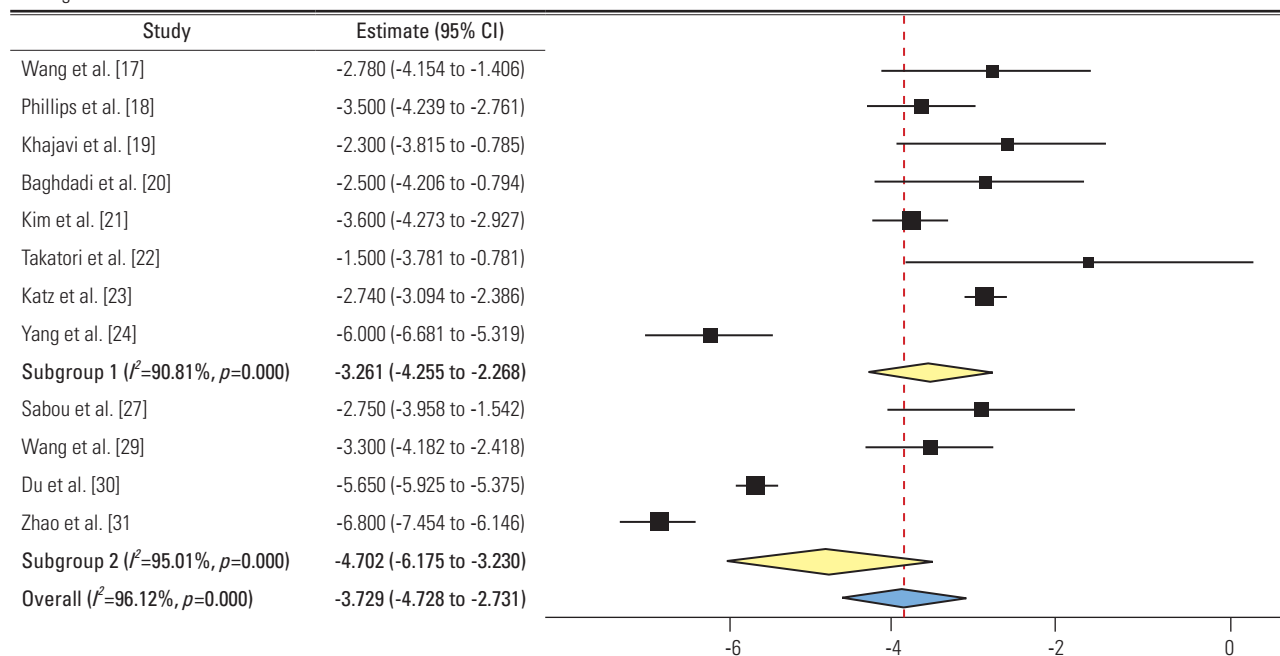
VAS leg

Fig. 3. Forest plot showing Visual Analog Scale (VAS) leg (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.
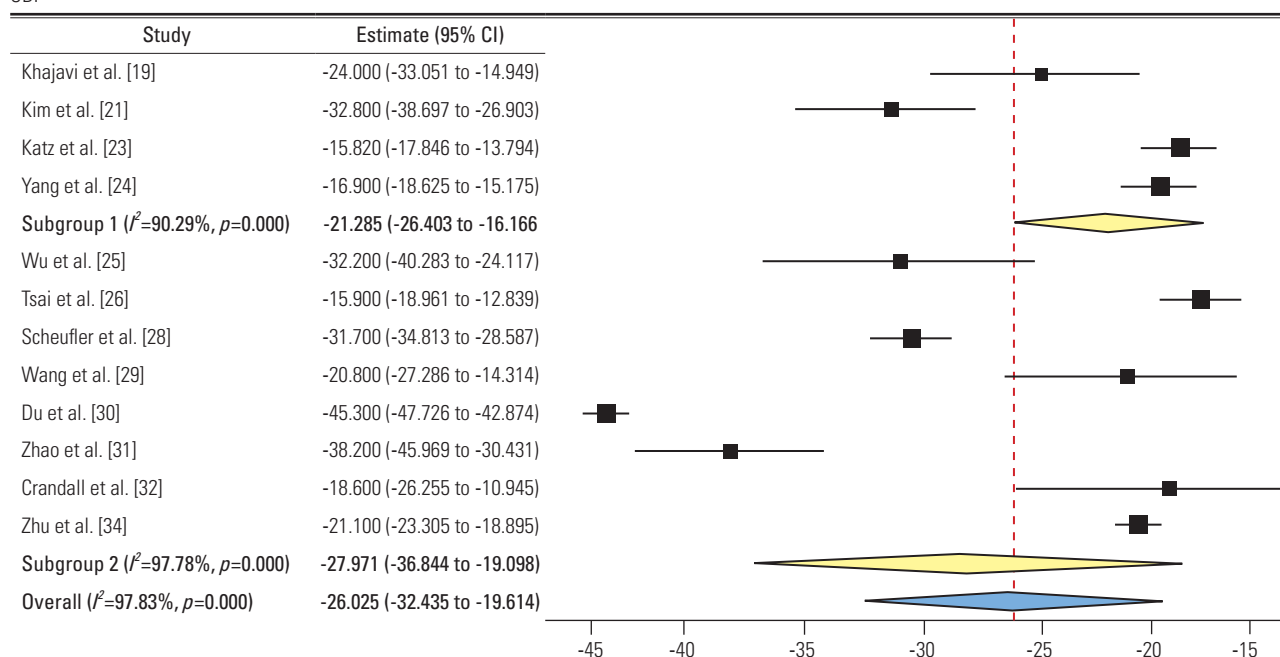
ODI

Fig. 4. Forest plot showing Oswestry Disability Index (ODI) (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.

studies except one showed an increased LL postoperatively [26]. The difference in subgroups was not significant.

3) Sagittal vertical axis (Fig. 7)
A total of nine studies reported the pre and post-interven-

tion SVA. Four and five studies showed an SMD of −5.59 (95% CI, −10.32 to −0.87; I^2=93.14%) and −1.93 (95% CI, −3.02 to −0.83; I^2=88.6%) in groups L and P, respectively. All studies showed a decreased SVA postoperatively. The difference in subgroups was not significant.
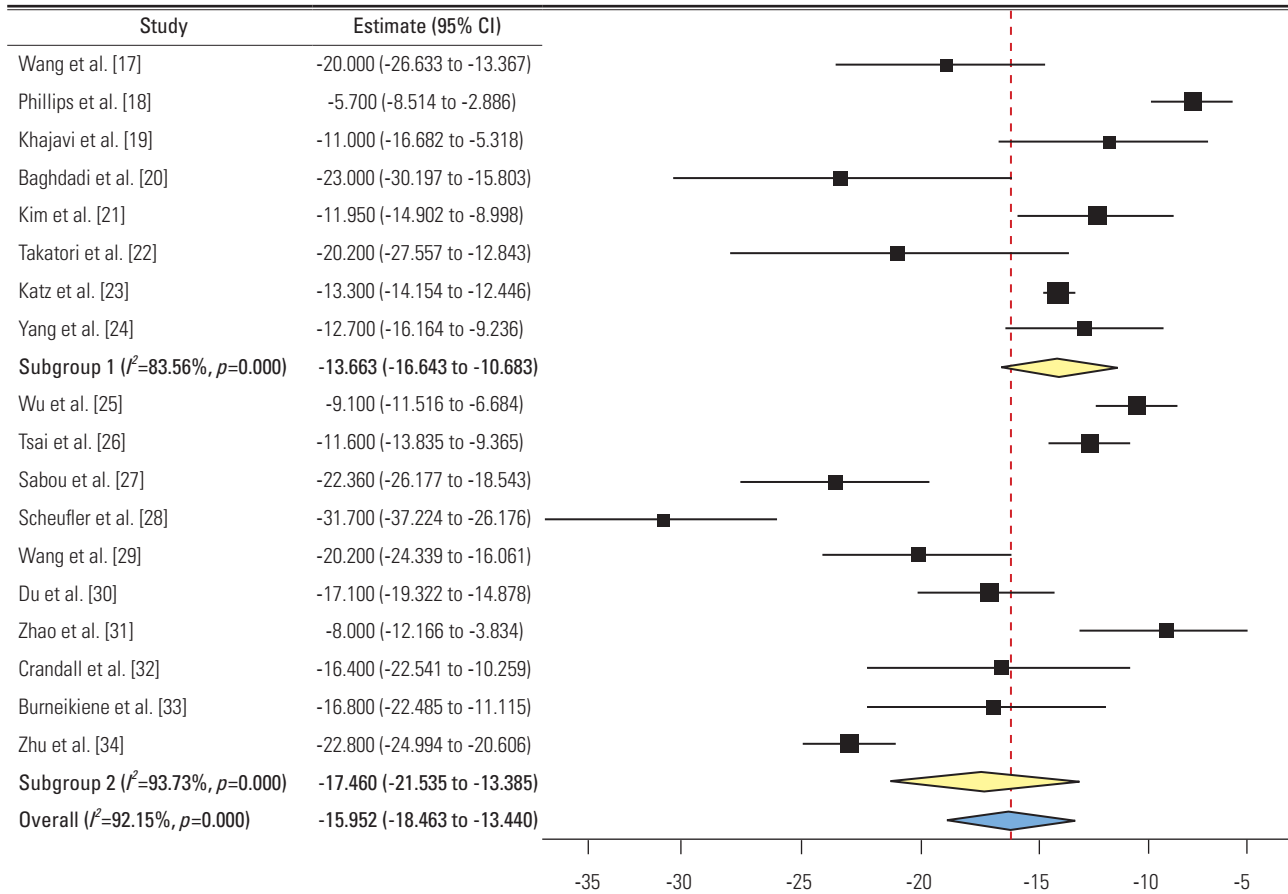
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Coronal Cobbs

Study	Estimate (95% CI)	
Wang et al. [17]	-20.000 (-26.633 to -13.367)	
Phillips et al. [18]	-5.700 (-8.514 to -2.886)	
Khajavi et al. [19]	-11.000 (-16.682 to -5.318)	
Baghdadi et al. [20]	-23.000 (-30.197 to -15.803)	
Kim et al. [21]	-11.950 (-14.902 to -8.998)	
Takatori et al. [22]	-20.200 (-27.557 to -12.843)	
Katz et al. [23]	-13.300 (-14.154 to -12.446)	
Yang et al. [24]	-12.700 (-16.164 to -9.236)	
Subgroup 1 (I^2=83.56%, p=0.000)	-13.663 (-16.643 to -10.683)	
Wu et al. [25]	-9.100 (-11.516 to -6.684)	
Tsai et al. [26]	-11.600 (-13.835 to -9.365)	
Sabou et al. [27]	-22.360 (-26.177 to -18.543)	
Scheufler et al. [28]	-31.700 (-37.224 to -26.176)	
Wang et al. [29]	-20.200 (-24.339 to -16.061)	
Du et al. [30]	-17.100 (-19.322 to -14.878)	
Zhao et al. [31]	-8.000 (-12.166 to -3.834)	
Crandall et al. [32]	-16.400 (-22.541 to -10.259)	
Burneikiene et al. [33]	-16.800 (-22.485 to -11.115)	
Zhu et al. [34]	-22.800 (-24.994 to -20.606)	
Subgroup 2 (I^2=93.73%, p=0.000)	-17.460 (-21.535 to -13.385)	
Overall (I^2=92.15%, p=0.000)	-15.952 (-18.463 to -13.440)	

-35 -30 -25 -20 -15 -10 -5

Fig. 5. Forest plot showing coronal Cobbs (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.

5. Operative outcomes

Operative parameters were compared between group L, MIS-P subgroup, and Op-P subgroup. Only one study in group L [17], four studies in the MIS-P subgroup [28-31], and four studies in the Op-P subgroup [25,26,33,34] reported the total operative time and blood loss. The mean number of interbody fusion levels was 3.7 in group L (86 interbody fusions in 23 patients), 2.11 in the MIS-P subgroup (366 interbody fusions in 173 patients), and 2.49 in the Op-P subgroup (519 interbody fusions in 208 patients). Group L had significantly more interbody levels than both MIS-P and Op-P subgroups ($p<0.05$).

1) Operative time (Fig. 8)
Only one study in group L reported total operative time with a mean of 401 minutes (95% CI, 351 to 450.9) [17]. Five studies in group L reported only lateral operative team (interbody fusion time), which was pooled to 170.14

minutes (95% CI, 114.5 to 225.6) [18,19,21,23,24]. In group P, the MIS-P subgroup (four studies) had pooled total operative time of 233.86 minutes (95% CI, 177.09 to 290.6; I^2=98.4%) while the Op-P subgroup (four studies) had pooled total operative time of 380.23 minutes (95% CI, 283.5 to 476.9; I^2=97.4%). A significant difference in total operative time was found between group L and MIS-P subgroup ($p<0.05$) while no difference was found between group L and Op-P subgroup.

2) Blood loss (Fig. 9)
Only one study in group L reported a mean total blood loss of 477 mL (95% CI, 201.7 to 752.2) [17]. Three studies in group L reported only lateral blood loss pooled at 86.93 mL (95% CI, 66.8 to 107) [19,21,24]. In group P, the MIS-P subgroup (four studies) had pooled total blood loss of 385.05 mL (95% CI, 224.4 to 545.7; I^2=98.6%) while the Op-P subgroup (four studies) had pooled total blood loss of 1,325.6 mL (95% CI, 1,004.4 to 1,646.7; $I2$=91.6%). A
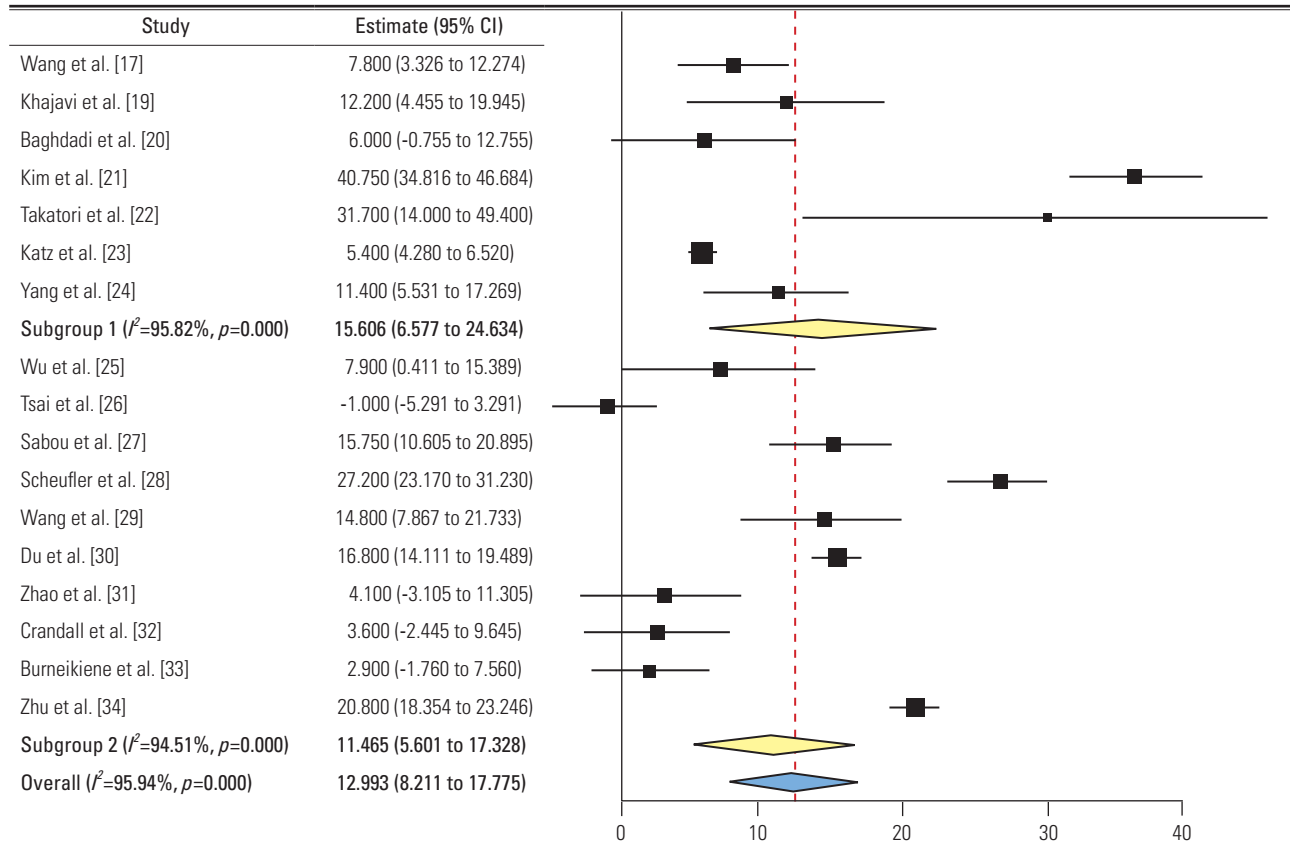
Lumbar lordosis

Study	Estimate (95% CI)
Wang et al. [17]	7.800 (3.326 to 12.274)
Khajavi et al. [19]	12.200 (4.455 to 19.945)
Baghdadi et al. [20]	6.000 (-0.755 to 12.755)
Kim et al. [21]	40.750 (34.816 to 46.684)
Takatori et al. [22]	31.700 (14.000 to 49.400)
Katz et al. [23]	5.400 (4.280 to 6.520)
Yang et al. [24]	11.400 (5.531 to 17.269)
Subgroup 1 (I^2=95.82%, p=0.000)	15.606 (6.577 to 24.634)
Wu et al. [25]	7.900 (0.411 to 15.389)
Tsai et al. [26]	-1.000 (-5.291 to 3.291)
Sabou et al. [27]	15.750 (10.605 to 20.895)
Scheufler et al. [28]	27.200 (23.170 to 31.230)
Wang et al. [29]	14.800 (7.867 to 21.733)
Du et al. [30]	16.800 (14.111 to 19.489)
Zhao et al. [31]	4.100 (-3.105 to 11.305)
Crandall et al. [32]	3.600 (-2.445 to 9.645)
Burneikiene et al. [33]	2.900 (-1.760 to 7.560)
Zhu et al. [34]	20.800 (18.354 to 23.246)
Subgroup 2 (I^2=94.51%, p=0.000)	11.465 (5.601 to 17.328)
Overall (I^2=95.94%, p=0.000)	12.993 (8.211 to 17.775)

Fig. 6. Forest plot showing lumbar lordosis (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.

SVA

Study	Estimate (95% CI)
Baghdadi et al. [20]	-1.100 (-3.040 to 0.840)
Kim et al. [21]	-10.720 (-13.092 to -8.348)
Takatori et al. [22]	-8.000 (-11.420 to -4.580)
Yang et al. [24]	-2.800 (-5.298 to -0.302)
Subgroup 1 (I^2=93.14%, p=0.000)	-5.597 (-10.323 to -0.871)
Tsai et al. [26]	-0.090 (-1.211 to 1.031)
Sabou et al. [27]	-1.120 (-2.797 to -0.557)
Scheufler et al. [28]	-2.360 (-2.981 to -1.739)
Wang et al. [29]	-3.100 (-6.046 to -0.154)
Du et al. [30]	-3.070 (-3.226 to -2.914)
Subgroup 2 (I^2=88.67%, p=0.000)	-1.930 (-3.024 to -0.836)
Overall (I^2=90.93%, p=0.000)	-3.167 (-4.371 to -1.962)

Fig. 7. Forest plot showing sagittal vertical axis (SVA) (subgroup 1: group L, subgroup 2: group P). CI, confidence interval.

significant difference was found between group L and the Op-P subgroup (p<0.05).

3) Fusion rate (Fig. 10)
A total of 10 studies reported the fusion rate. Four studies in group L had pooled fusion rate of 97.8% (95% CI, 94.8

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Total operative time (subgroup 1: MIS lateral, subgroup 2: MIS posterior, subgroup 3: open posterior)
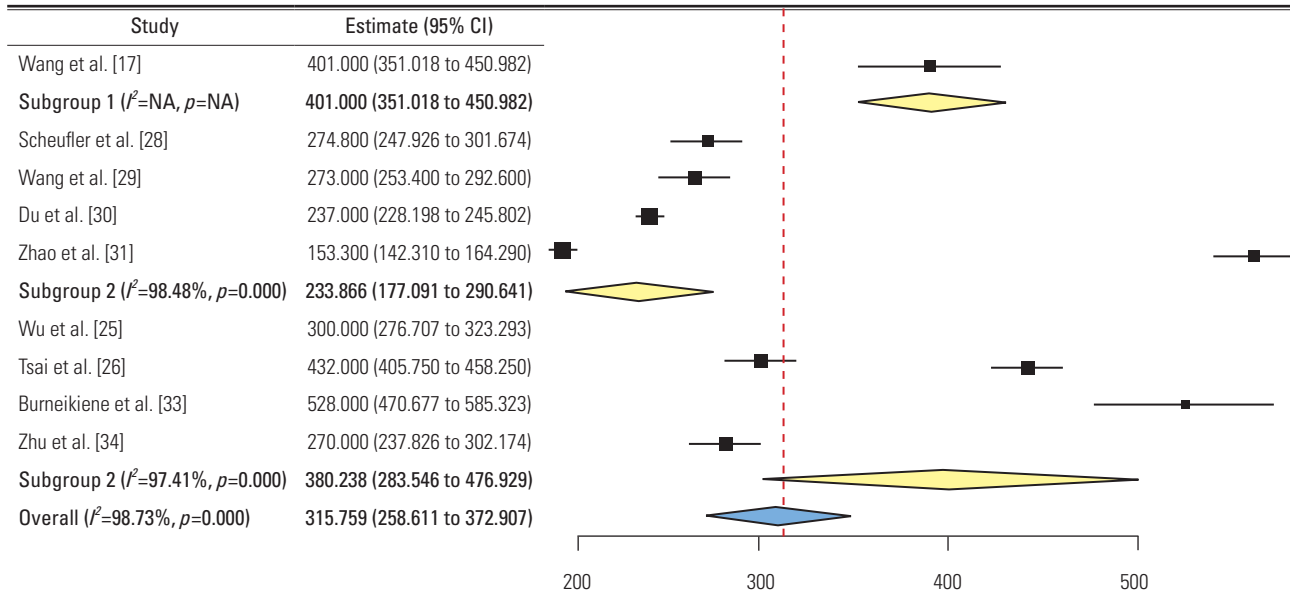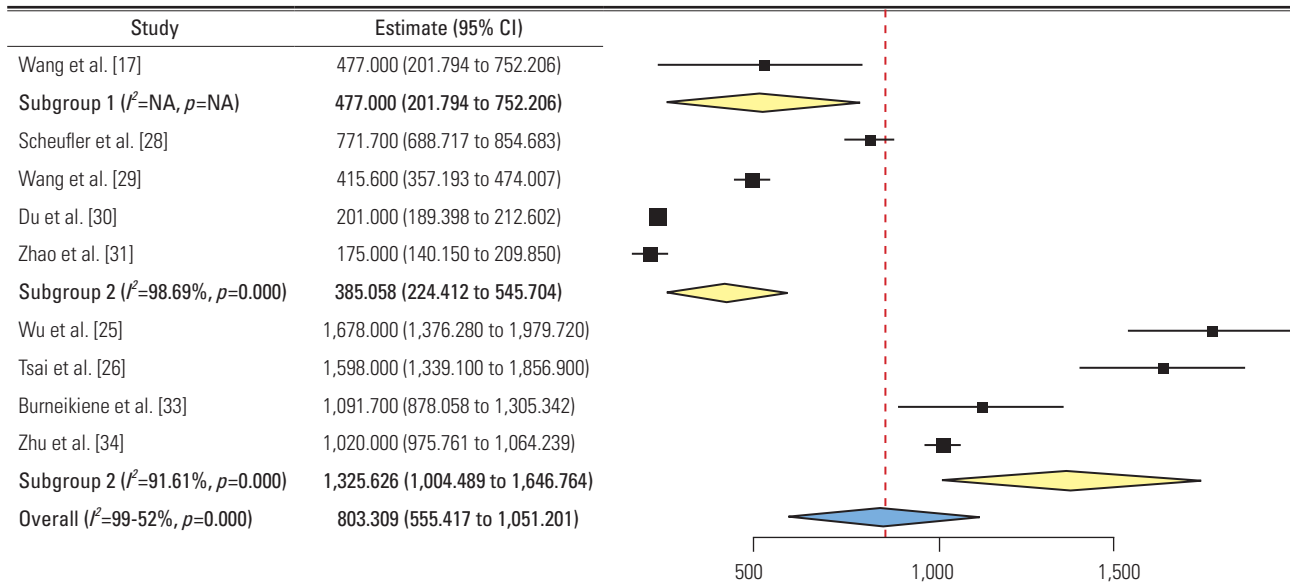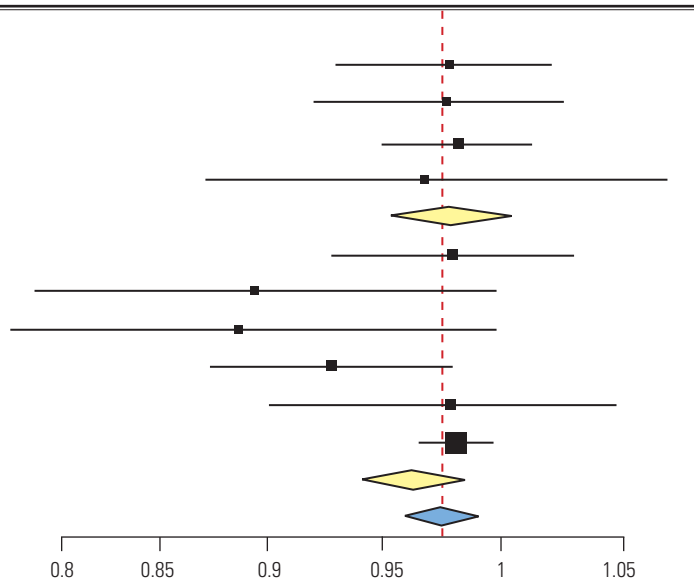

Fig. 8. Forest plot showing total operative time (subgroup 1: group L, subgroup 2: minimally invasive surgery [MIS] posterior subgroup, subgroup 3: open posterior subgroup). CI, confidence interval; NA, not available.

Total blood loss (subgroup 1: MIS lateral, subgroup 2: MIS posterior, subgroup 3: open posterior)
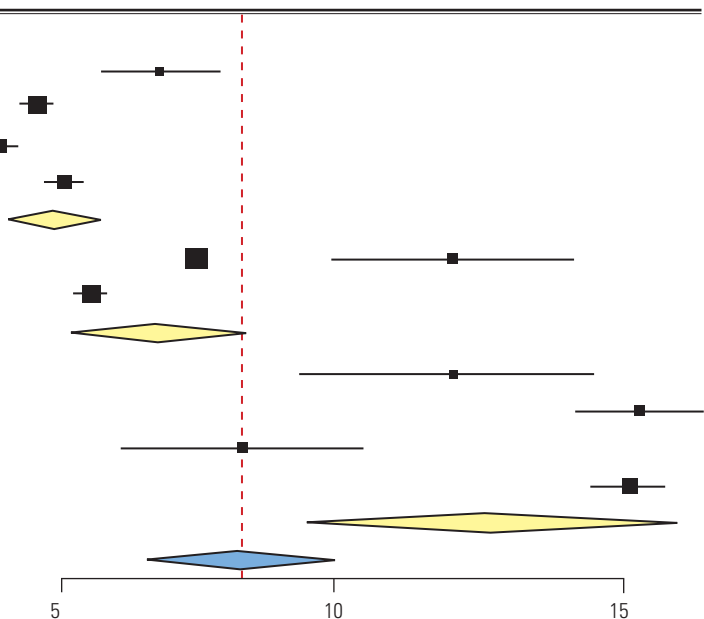

Fig. 9. Forest plot showing total blood loss (subgroup 1: group L, subgroup 2: minimally invasive surgery [MIS] posterior subgroup, subgroup 3: open posterior subgroup). CI, confidence interval; NA, not available.

to 100; I^2=0%). Six studies in group P had pooled fusion rate of 96.6% (95% CI, 94.2 to 98.9; I^2=25.4%). No significant difference was found between the two groups.

4) Length of hospital stay (Fig. 11)
Four studies in group L had pooled LOHS of 4.15 days (95% CI, 2.79 to 5.5; I^2=90.9%). In group P, the MIS-P

subgroup (two studies) had pooled LOHS of 6.25 days (95% CI, 4.59 to 7.92; I^2=98.1%) while the Op-P subgroup (four studies) had pooled LOHS of 13.54 days (95% CI, 9.34 to 17.74; I^2=94.1%). A significant difference was found between group L and the Op-P subgroup ($p<0.05$).

Fusion rate

Study	Estimate (95% CI)	Ev/Trt
Wang et al. [17]	0.979 (0.922 to 1.036)	23/23
Khajavi et al. [19]	0.977 (0.915 to 1.040)	21/21
Katz et al. [23]	0.982 (0.933 to 1.031)	27/27
Yang et al. [24]	0.962 (0.857 to 1.066)	12/12
Subgroup 1 (I^2=0%, p=0.989)	0.978 (0.948 to 1.009)	83/83
Wu et al. [25]	0.981 (0.931 to 1.032)	26/26
Scheufler et al. [28]	0.885 (0.762 to 1.007)	23/26
Wang et al. [29]	0.880 (0.753 to 1.007)	22/25
Du et al. [30]	0.938 (0.889 to 0.986)	90/96
Zhao et al. [31]	0.978 (0.919 to 1.038)	22/22
Zhu et al. [34]	0.979 (0.960 to 0.997)	231/236
Subgroup 2 (I^2=24.28%, p=0.252)	0.966 (0.942 to 0.989)	414/431
Overall (I^2=0%, p=0.651)	0.973 (0.959 to 0.987)	497/514

Fig. 10. Forest plot showing fusion rates (subgroup 1: group L, subgroup 2: minimally invasive surgery [MIS] posterior subgroup, subgroup 3: open posterior subgroup). CI, confidence interval; Ev/Trt, number of events/number of treatments.

Study	Estimate (95% CI)
Wang et al. [17]	6.170 (4.740 to 7.600)
Phillips et al. [18]	3.800 (3.232 to 4.368)
Khajavi et al. [19]	2.200 (1.430 to 2.970)
Yang et al. [24]	4.800 (4.008 to 5.592)
Subgroup 1 (I^2=90.98%, p=0.000)	4.153 (2.797 to 5.508)
Du et al. [30]	7.100 (6.840 to 7.360)
Zhao et al. [31]	5.400 (5.024 to 5.776)
Subgroup 1 (I^2=98.12%, p=0.000)	6.256 (4.590 to 7.922)
Wu et al. [25]	11.700 (8.679 to 14.721)
Tsai et al. [26]	17.200 (15.218 to 19.182)
Burneikiene et al. [33]	8.000 (5.634 to 10.366)
Zhu et al. [34]	16.900 (15.633 to 18.167)
Subgroup 2 (I^2=94.18%, p=0.000)	13.544 (9.343 to 17.744)
Overall (I^2=98.63%, p=0.000)	8.143 (6.302 to 9.983)

Fig. 11. Forest plot showing length of hospital stay (subgroup 1: group L, subgroup 2: minimally invasive surgery posterior subgroup, subgroup 3: open posterior subgroup). CI, confidence interval.

6. Complications (Table 3)

1) Dural tear
Pooled dural tear rate across two studies [17,23] in group L was 4% (95% CI, 1.4 to 9.4) compared to 7% (95% CI, 2 to 12) across four studies [25,28,31,33] in group P with no significant difference.

2) Wound related
Wound related complications including Wound infections, dehiscence, delayed healing, and seroma were reported in four studies in group L with a pooled rate of 7.5% (95% CI, 1 to 13.9) [18,20,22,23]. No significant difference was noted in comparison with group P with a pooled rate of 2.7% (95% CI, 1.1 to 4.3) across six studies [25-27,30,33,34].
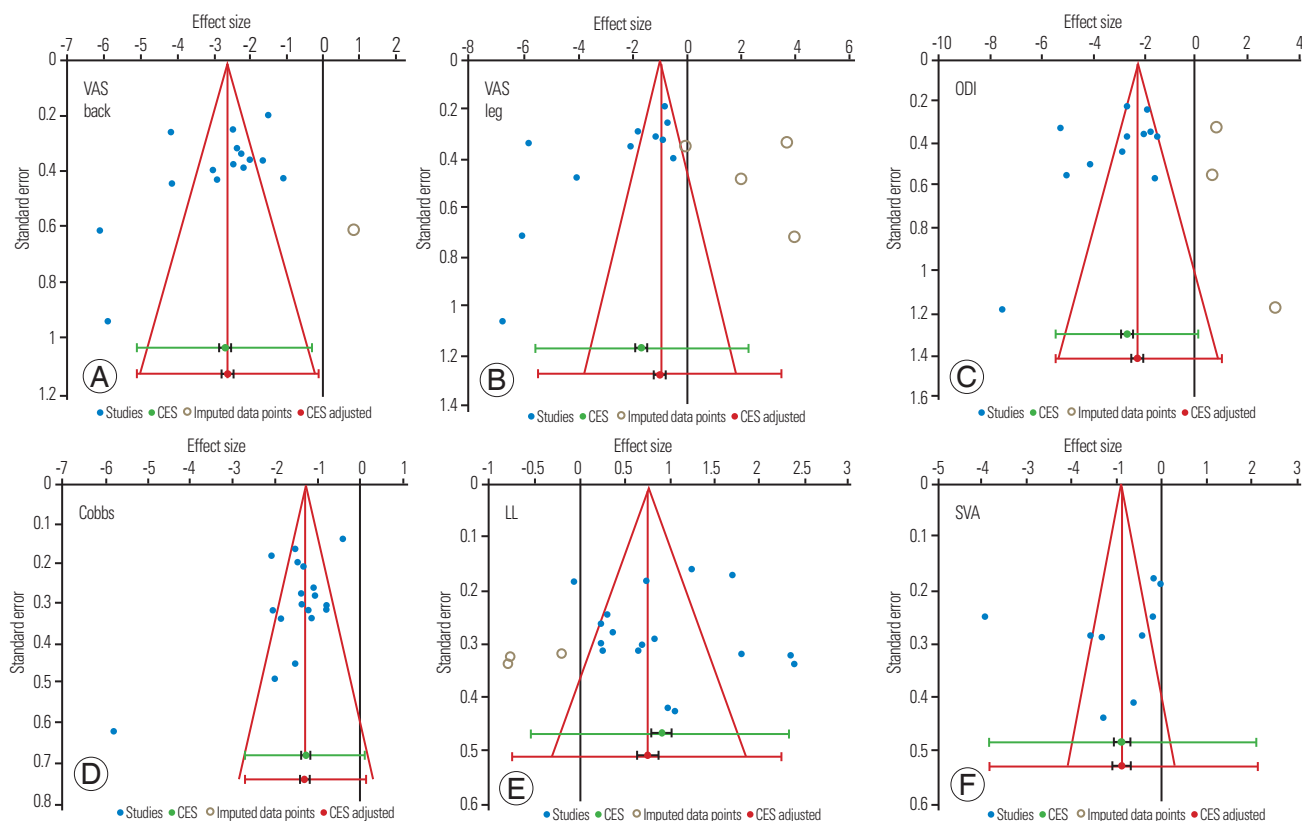
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Fig. 12. Funnel plots. **(A)** Visual Analog Scale (VAS) back. **(B)** VAS leg. **(C)** Oswestry Disability Index (ODI). **(D)** Cobbs. **(E)** Lumbar lordosis (LL). **(F)** Sagittal vertical axis (SVA). CES, combined effect size.

Table 3. Complications

Complications	Subgroup	No. of studies	No. of patients	No. of complications	Pooled rate (95% CI)	I^2 (%)
Dural tear	Lateral	2	50	2	4 (1.4 to 9.4)	0
	Posterior	4	107	10	7 (2 to 12)	10.9
Wound related	Lateral	4	179	12	7.5 (1 to 13.9)	44.32
	Posterior	6	368	14	2.7 (1.1 to 4.3)	0
Neurological deficit	Lateral	2	140	11	7.8 (3.4 to 12.3)	0
	Posterior	4	284	10	2.4 (0.1 to 4.8)	41.21
Transient sensori-motor defcit	Lateral	3	56	14	24.3 (13.1 to 35.4)	0
	Posterior	3	76	5	5.6 (5 to 10.7)	0
Implant or construct related	Lateral	3	68	6	7.3 (1.2 to 13.5)	0
	Posterior	5	439	71	14.9 (8.7 to 21.1)	74.4
Resurgery	Lateral	7	235	23	7.9 (4.3 to 11.4)	5.9
	Posterior	10	468	34	5.9 (2.5 to 9.3)	71.38
Pseudoarthrosis	Lateral	1	23	1	4.3 (-4 to 12.7)	NA
	Posterior	3	155	9	6.3 (-1 to 13.7)	61.27
Others						
Postoperative thigh pain	Lateral	4	88	8	7.7 (2.2 to 13.2)	0
Visceral injuries	Lateral	2	139	3	2 (-2 to 6)	NA
Retrograde ejaculation	Lateral	1	27	1	3.7 (3.4 to 10.8)	NA
Adult degenerative scoliosis	Posterior	8	414	43	8.6 (5.2 to 12.2)	43.18

CI, confidence interval; NA, not available.

3) Neurological deficit

Pooled rate of permanent neurological deficit across two studies [18,20] in group L was 7.8% (95% CI, 3.4 to 12.3) compared to 2.4% (95% CI, 0.1 to 4.8) across four studies [27,30,33,34] in group P with no significant difference.

4) Transient sensorimotor deficit

In group L, pooled rate of transient neurological deficit across three studies was 24.3 (95% CI, 13.1 to 35.4), which mainly included transient hip flexor weakness and thigh numbness [17,19,24]. Group P had pooled rate of 5.6% (95% CI, 5 to 10.7) across three studies [25,32,35]. The difference approached significance ($p<0.05$).

5) Implant or construct related

Complications included screw loosening, pull-out, and rod breakage. Pooled rate in group L across threes studies [17,20,22] was 7.3% (95% CI, 1.2 to 13.5) compared to 14.9% (95% CI, 8.7 to 21.1) across five studies [26,27,29,33,34] in group P with no significant difference.

6) Re-surgery

Pooled re-surgery rate across seven studies [17-20,22-24] in group L was 7.9% (95% CI, 4.3 to 11.4) compared to 6% (95% CI, 2.5 to 9.5) across 10 studies [25-34] in group P with no significant difference.

7) Pseudoarthrosis

Pooled pseudoarthrosis rate across one study [17] in group L was 4.3% (95% CI, 4 to 12.7) compared to 6.3% (95% CI, -1 to 13.7) across three studies [30,33,35] in group P with no significant difference.

8) Others

Complications, such as postoperative thigh pain, retrograde ejaculation, and visceral injuries, were reported only in group L. Pooled rate of postoperative thigh pain across four studies was 7.7% (95% CI, 2.2 to 13.2) [17,19,21,22]. The pooled rate of visceral injuries across two studies was 2% (95% CI, −2 to 6) [18,21]. Retrograde ejaculation was reported in only one patient in one study with a rate of 3.7% (95% CI, 3.4 to 10.8) [23]. Complications of adjacent segment degeneration (ASD), such as vertebral fractures, disc degeneration, and proximal junctional kyphosis were reported only in group P across eight studies with a pooled rate of 8.6% (95% CI, 5.2 to 12.2) [26,27,30-35].

9) Funnel plots

Funnels plot for clinical (VAS back, VAS leg, and ODI) and radiographic outcomes (Cobb's angle, LL, and SVA) showed asymmetry on visual inspection (Fig. 12). In clinical outcomes, studies were missing from the bottom half of the plot, indicating publication and selective outcome reporting bias. Additionally, heterogeneity across the studies was high due to the difference in patient selection and intervention, which could have led to asymmetry in funnel plots of radiographic outcomes.

Discussion

ADS should be differentiated from adult idiopathic scoliosis as it is characterized by progressive spinal element degeneration due to aging, which is usually asymmetric, leading to coronal and sagittal malalignment. It is also known as "*de novo* scoliosis" or "primary degenerative scoliosis" or "type 1 adult scoliosis" [1]. Not only the pathophysiology is different, but the clinical presentation also varied as patients with ADS present with more complaints of back pain, neurogenic claudication, and radiculopathy than deformity cosmetic concerns. Hence, the treatment goals of patients with ADS are different from patients with other deformities. Adequate decompression is equally important along with deformity correction for patient satisfaction and health-related quality of life (HRQOL) improvement [3]. Thus, the authors conducted this systematic review to generate a piece of high-quality evidence to compare the outcomes of deformity correction and direct decompression from the posterior approach versus indirect decompression from the lateral approach.

The systematic reviews in existing literature mostly compared different lumbar interbody fusion procedures in degenerative disc disease [36-39]. Very few systematic reviews have analyzed the surgical outcomes in patients with adult scoliosis, and most of them had included a heterogeneous cohort of patients, with different curve and procedure types [14-16,40]. This systematic review included only studies reporting ADS with almost similar curve types and tried to analyze the outcomes of different interbody fusion techniques. These studies were observational; however, all were of good quality on assessment. Additionally, subgroup analyses were done to separately report the relevant outcomes, such as blood loss, operative time, and LOHS, for open and minimally invasive procedures.

Most of the studies included VAS (back and leg) and ODI as patient-reported outcome measures (PROM) while other HRQOL measures, such as EuroQol-5 dimension (EQ5D), 36-item Short Form Health Survey (SF-36), and Scoliosis Research Society-22 (SRS-22), were missing; thus, they could not be analyzed. All studies showed improvement in VAS back (lateral approach: −55% reduction, posterior approach: −58% reduction) and VAS leg (lateral group: −60% reduction, posterior group: −70% reduction) postoperatively. No statistically significant difference was found between the two groups. The maximum change in VAS was seen in studies with the highest preoperative VAS score for VAS back [20,34] and leg [24,31]. Ledonio et al. [16], in a meta-analysis on ADS, showed that preoperative values for VAS were significantly associated with treatment effect. Similarly, ODI also improved postoperatively in both the groups (lateral group: −46%, posterior group: −58%) with no significant difference. Both VAS and ODI improvement in this meta-analysis in both groups reached MCID values [41-43]. Therefore, both direct and indirect decompression can give equal and promising functional outcomes in modest curves of degenerative scoliosis.

All the studies showed a reduced coronal Cobb's postoperatively in both the groups (lateral group: −56.5%, posterior group: −62.3%). Studies with maximum preoperative Cobb's showed maximum treatment effect, consistent with the study results by Ledonio et al. [16]. LL also improved postoperatively in both the groups, except in one study by Tsai et al. [26], where deterioration in the mean LL occurred by 1° after instrumented PLIF in 58 patients of degenerative lumbar scoliosis. SVA postoperatively improved in all studies in both groups. However, most of the studies did not mention the standing full-length X-rays, which are required for correct radiographic SVA measurement, accounting for heterogeneity in measurements. Few previous comparative studies showed better radiological outcomes with good sagittal alignment restoration with lateral interbody fusion over posterior interbody fusion [44,45]. However, no significant difference was seen between the two groups about radiological outcomes in our study. This observation is also supported by previous systematic reviews [37,46], which have not shown any significant difference in radiographic outcomes on LLIF comparison with traditional TLIF/PLIF.

We separately performed a subgroup analysis for operative parameters, such as blood loss, operative time, and LOHS, for open and MIS, due to the heterogeneity in the surgical procedures. The pooled total operative time of group L (401 minutes) was significantly more than the MIS-P subgroup (238.8 minutes), while it was comparable to the Op-P subgroup (380.2 minutes). Positioning of patients from lateral to prone for posterior instrumentation after interbody fusion (LLIF/XLIF/OLIF) explains the increased operative time in the lateral approach for ADS deformity correction. Additionally, the average number of interbody fusion levels was significantly more in group L compared with group P, this could explain the shorter operative time in group P. The pooled total blood loss of group L (477 mL) was comparable with the MIS-P subgroup (385 mL), while significantly different from the Op-P subgroup (1,325 mL). Li et al. [38] conducted a systematic review for comparison of OLIF versus MI-TLIF in degenerative disc disease and reported the advantage of OLIF over MI-TLIF in operative time and blood loss while no differences were found in LOHS. While conducting this meta-analysis, the authors found that most of group L reported only lateral operative time and blood loss (excluding posterior instrumentation operative time and blood loss), which could not be compared to group P [18,19,21,23,24]. A significant difference was found in LOHS on the comparison of group L (4.15 days) and the Op-P subgroup (8.1 days), while it was comparable with the MIS-P subgroup (6.25 days).

No significant difference was found in the fusion rates and pseudoarthrosis between the two groups in this study. All included studies had a minimum follow-up period of 1 year; however, the range of follow-up was very wide from 1 to 13 years, which could have led to a bias in the comparison of fusion and pseudoarthrosis rates. In a meta-analysis conducted by Teng et al. [36], 30 studies were included for comparing various lumbar interbody fusion techniques in degenerative disc disease and found no difference in fusion rates between ALIF, LLIF, PLIF, and TLIF.

Complications, such as transient sensorimotor weakness, were found significantly more in group L (24.3%) than in group P (5.6%). Transient thigh numbness was most commonly reported in group L, followed by transient hip flexor weakness. Hijji et al. [47], in a systematic review on complication rates of LLIF in 6,819 patients (63 articles), reported transient neurological weakness as the most common complication (36.07%), which is considered a result of trauma to the psoas muscle during

the approach and is probably not related to direct nerve injury. Few complications were found to be approach-specific in our study. Postoperative thigh pain (7.7%), visceral injuries (2%), and retrograde ejaculation (3.7%) were seen only with the lateral approach. Gammal et al. [48], in a systematic review of 24 studies assessing thigh symptoms after LLIF, reported a high incidence of postoperative thigh or groin pains (9.2%–43%), attributable to psoas manipulation and edematous reaction. Proximity to abdominal viscera, peritoneum, and vessels makes complication rates of visceral and vascular injuries higher in lateral interbody fusion [49]. Injury to the sympathetic chain can lead to retrograde ejaculation as seen in one patient in a study by Katz et al. [23]. Complications, such as ASD (8.6%), were seen only in group P. Preservation of both anterior and posterior ligamentous structures in LLIF/OLIF has the theoretical advantage of better biomechanical stability with fewer ASD chances. However, the literature reported no consistent findings in substantiating that any of the LIF techniques is superior concerning ASD [50]. Moreover, relatively less duration of the follow-up period in these new lateral approach studies as compared to the traditional posterior approach could have led to underreporting of ASD in group L.

This study has a few limitations. Due to the lack of comparative studies or RCT, high heterogeneity was noted due to the difference in inclusion criteria of patients, surgeon's expertise, and choice of surgical procedure across the selected studies. Only one study [17] in group L reported total operative time and blood loss while most studies [18,19,21,23,24] reported only lateral interbody fusion time and blood loss. Pelvic parameters were not reported in most of the selected studies; thus, analyses could not be done regarding the change in pelvic parameters postoperatively. L5–S1 interbody fusion is difficult from a lateral approach due to the over-riding of the iliac crest and vascular anatomy at this level; thus, ALIF or TLIF was performed when necessary at L5–S1 level in group L. The use of biologics as an adjunct for fusion could account for heterogeneity in the fusion outcomes. The comparison of complications revealed large differences in the percentage of complications between the two groups, CI of pooled data are very wide due to heterogeneity making the difference non-significant in the pooled analysis. Few studies were industry sponsored [17,18,32] while authors of few studies [19,23,28,29] were likely to receive benefits from a commercial party due to the use of interbody devices,

which could account for funding bias in these studies.

Prospective comparative studies and RCTs with SRS-22, EQ5D, and SF-36 as PROM are required in the future for high-quality evidence. Additionally, the measurement of radiographic parameters should be uniform, preferably using an erect 91.44-cm anteroposterior and lateral X-ray of the whole spine with reporting of coronal, sagittal, and pelvic parameters.

Conclusions

Both posterior (PLIF/TLIF) and lateral (LLIF/XLIF/OLIF) lumbar interbody fusion procedures achieve similar functional and radiographic outcomes in patients with mild to moderate curves of ADS. Deformity correction from the lateral approach has an advantage in blood loss and LOHS over the Op-P subgroup. The MIS-P subgroup has less operative time than group L but with comparable blood loss and LOHS. No significant difference was found in the fusion rates, pseudoarthrosis, and complications between the two groups except for transient sensorimotor deficits. Few complications were found as approach-specific in each group.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Supplementary Materials

Supplementary materials can be available from https://doi.org/10.31616/asj.2022.0040. Supplement 1. Literature search strings. Supplement 2. National Institutes of Health quality assessment of included studies.

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