Systematic Review and Meta-Analysis

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Pedicle screw versus hybrid instrumentation in adolescent idiopathic scoliosis

A systematic review and meta-analysis with emphasis on complications and reoperations

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Abstract

Background: Incidence of complications and reoperations between pedicle screw (PS) and hybrid instrumentations (HI) are still controversial in adolescent idiopathic scoliosis (AIS) patients. A systematic review and meta-analysis were performed to compare overall complications, reoperations, and radiographic outcomes between the 2 constructs.

Methods: Strictly followed the PRISMA 2009 guidelines, the MEDLINE, EMBASE, and the Cochrane Library databases were used to search for literatures up to April 2016, addressing PS versus HI in AIS patients. The Newcastle–Ottawa scale was adopted to assess the quality of the studies. Data on complications, reoperations, Cobb angle of major curve, thoracic kyphosis, and proximal junctional measurement were extracted from the included studies. RevMan 5.3 and SPSS 21.0 were used for statistical analysis.

Results: Twenty-four case-control studies with a total of 3042 AIS patients (1582 PS, 1460 HI) were included, consisting of 1 randomized controlled trial, 1 prospective study, and 22 retrospective studies. Decreased overall complications (95% CI 0.42–0.87, $P=.007$; $I^2=38\%$) and reoperations (95% CI 0.22–0.62, $P=.0001$; $I^2=0\%$) were found in PS group compared with HI group. As regard to reasons for reoperations, increased incidence of pseudarthrosis ($P=.005$), dislodged instrumentation ($P=.005$), and deep infection ($P=.016$) occurred in HI group. PS group achieved a better coronal correction (95% CI −7.06 to −4.54, $P<.00001$; $I^2=34\%$), but HI group was more powerful in restoring thoracic kyphosis (95% CI −7.88 to −3.70, $P<.00001$; $I^2=60\%$), and no significant differences were found in proximal junctional measurement (95% CI −0.88 to 1.54, $P=.59$; $I^2=0\%$) between the 2 constructs.

Conclusion: Compared with hybrid instrumentation, pedicle screw construct provides better coronal correction but less thoracic kyphosis restoring, with decreased incidence of overall complications and reoperations in AIS patients. As regard to the pedicle screw construct, the most common reasons for reoperation are malposition, deep infection, pseudarthrosis, and prominent implant.

Abbreviations: AIS = adolescent idiopathic scoliosis, HI = hybrid instrumentations, NOS = Newcastle–Ottawa scale, PS = pedicle screw.

Keywords: adolescent idiopathic scoliosis, complications, hybrid instrumentation, meta-analysis, pedicle screw construct

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a tridimensional musculoskeletal deformity afflicted 1% to 3% adolescents at danger age of 10 to 16 years. Cobb angle of major curve greater than 40° is the generally agreed threshold for surgery. Untreated AIS patients may result in pulmonary limitations, back pain, appearance, and overall function affects.[1]

From the Harrington rod insertion to the Cotrel–Dubousset instrumentation, much improvement has been made in tridimensional correction and mechanical conservation.[2,3] Hybrid instrumentation, the third-generation orthotic tool, is constituted with lumbar pedicle screws, hooks, and wires. The deformity correction and stabilization are enhanced with lumbar pedicle screw.[4,5] The using of thoracic pedicle screw was pioneered by Suk,[6] and multiplanar corrections and stable fixation of all-pedicle screw construct were reported.[7–9] However, complications related to pedicle screw implanting, such as screw malposition, neural injury, dislodged or prominent instrumentation, have caught many scholars' attention.[10–15]

To our limited knowledge, 1 meta-analysis has got overview of the power of restoring thoracic kyphosis between pedicle screw (PS) and hybrid instrumentations (HI).[16] However, no systematic review or meta-analysis has compared complications and reoperations between the 2 instrumentations. The purpose of this study is to compare complications, reoperations, and radio-

Editor: Bernhard Schaller.

Neither the entire paper nor any part of its content has been published or has been accepted elsewhere.

As a meta-analysis, all raw data of this study are extracted from the included studies. The datasets supporting the conclusions of this article are available in the included studies.

LX and ML conceived the design of the study. ML, NL, and MS performed and collected the data and contributed to the design of the study. ML and NL prepared and revised the manuscript. All authors read and approved the final content of the manuscript.

ML and NL contributed equally to this work.

The authors have no conflicts of interest to disclose.

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Medicine (2017) 96:27(e7337)

Received: 7 December 2016 / Received in final form: 31 May 2017 / Accepted: 1 June 2017

http://dx.doi.org/10.1097/MD.0000000000007337

graphic outcomes (Cobb angle of major curve, thoracic kyphosis, and proximal junctional measurement) between PS versus HI in AIS patients.

2. Methods

2.1. Search strategy

Strictly followed by the PRISMA 2009 guidelines, the MEDLINE, EMBASE, and the Cochrane Library databases were used for searching literatures up to April 2016. The keywords included "screw" AND "hybrid" AND "adolescent idiopathic scoliosis." Any related articles in databases and references of involved articles were browsed to prevent the omission of potential articles. Two authors (ML, NL) searched and extracted the data independently. Four thousand sixty-seven potentially relevant studies were identified from electronic databases.

2.2. Inclusion and exclusion criteria

Studies were included if they met all the following inclusion criteria: AIS diagnosis, controlled trial specified "PS" and "HI," and complications or radiographic outcomes of final follow-up were reported.

Articles were excluded if they met one of the following inclusion criteria: annual meeting abstract, congenital or neuromuscular scoliosis patients were included, case study only reported "PS" or "HI," radiographic outcomes without final follow-up, and anterior-posterior approach included. To elucidate the possible repetition of patients, studies were published with similar study period, same authors and institutions were excluded, and we chose the most suitable one from articles reported.

2.3. Data extraction

Two reviewers (ML and MS) extracted data from the included papers. The extracted data included the following information: study ID, publication data, and nationality; study design and period, minimum follow-up, sample size, gender, age of surgery, fused levels; Lenke classification; complications and reoperations; and Cobb angle of the major curve, thoracic kyphosis (T5–T12), proximal junctional measurement (Cobb angle between the most proximal instrumented vertebra and the segment 2 levels cephalad) of final follow-up.

In Sabharwal's study, the data were presented as mean value and the 95% CI, and the data were transformed into mean ± SD.[17] In Lonner's article, the subgroup data of monoaxial and polyaxial pedicle screw groups were combined into PS group.[18] In Fu's study, the subgroup data of hook and wire groups were combined into HI group.[19] The transformation formula was recommended by the Cochrane Handbooks version 5.1.0.

2.4. Quality and bias assessment

The quality assessment of potentially included studies was independently appraised by two reviewers (ML and NL) using the Newcastle–Ottawa scale (NOS),[20] which was recommended by the Cochrane Handbooks version 5.1.0 to evaluate the risk of bias of nonrandomized controlled studies. According to the NOS, a study was judged on 3 broad topics: the selection of the study groups, the comparability of the groups, and the ascertainment of the exposure for controlled studies. Study with a score less than 6 was regarded as high risk of bias and it should not be included.

The funnel plot was used to assess publication bias. If there was no publication bias, the studies were symmetrically distributed on both the sides of the pooled proportion line. The funnel plot would be asymmetrical in the case of publication bias, because the absence of studies would distort the distribution on the scatter plot.

2.5. Statistical analysis

RevMan 5.3 (the Cochrane Collaboration, Oxford, UK) was used for pooling the data. The heterogeneity was evaluated using Q statistics and *I*-squared, and a fixed effect model was used

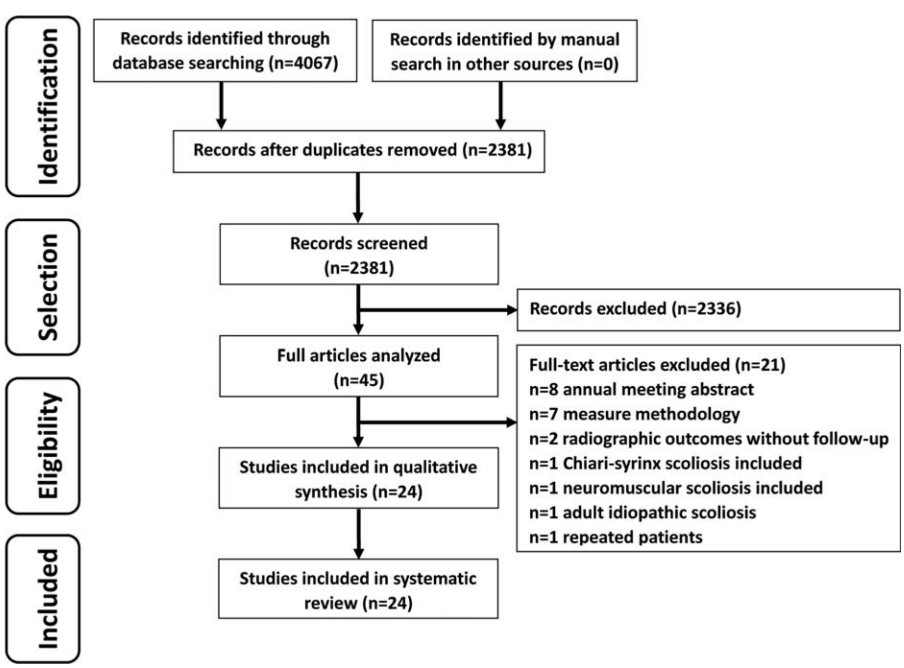

Figure 1. Flow diagram of study selection.

Table 1

The basic characteristics and quality assessment of included studies.

Author and year	Country	Study type	Study period	Follow-up (y)	Group	Number	Gender female /male	Age (y)	Lenke classification 1/2/3/4/5/6	Major curve Cobb Pre (°)	Flexibility (%)	Fused levels	The NOS
Suk et al 1995 [6]	Korea	Retro	1987–1991	≥2	S	24	NR	16.3	NR	58	48	NR	7
					H	23	NR		NR	51	56	NR	
Kim et al 2006 [21]	USA	Retro matched	1991–2002	2	S	29	20/9	14.8 ± 1.24	14/3/8/1/0/3	62 ± 12	48 ± 16	11.7 ± 1.6	8
					H	29	25/4	14.7 ± 2.02	14/3/8/1/0/3	60 ± 9	47 ± 17	13.0 ± 1.2	
Kuklo et al 2007 [22]	USA	Retro	1990–2004	≥2	S	295	NR	NR	NR	NR	NR	NR	6
					H	423	NR	NR	NR	NR	NR	NR	
Lowenstein et al 2007 [23]	USA	Retro matched	1998–2004	NR	S	17	15/2	14.1 (10,18)	NR	54.88 ± 12.48	NR	NR	8
					H	17	14/3	13.5 (10,16)	NR	54.06 ± 9.85	NR	NR	
Qiu et al 2007 [24]	China	Retro	2001–2005	≥1	S	20	15/5	14.4 ± 24	NR	52 ± 12	55.9 ± 13.0	9.7 ± 1.7	8
					H	20	16/4	14.5 ± 15	NR	54 ± 15	56.4 ± 14.2	9.5 ± 1.4	
Li et al 2008 [25]	China	Retro	2000–2004	2	S	30	24/6	13.4	15/0/7/0/2/6	60 ± 10	47 ± 14	12.4 ± 1.5	8
					H	30	23/7	14.3	15/0/7/0/2/6	61 ± 9	45 ± 12	12.8 ± 1.8	
Silvestre et al 2008 [26]	Italy	Retro	1996–2000	6.7	S	25	16/9	16.4	9/9/3/4/0/0	88	25.62	11.84	8
					H	27	23/4	14.9	11/9/3/4/0/0	92	27.23	12.89	
Karatoprak et al 2008 [27]	Turkey	Retro	1998–2004	≥2	S	22	17/5	14.5	NR	61.8	47.0	12.3	7
					H	26	19/7	15.6	NR	60.5	33.5	12.1	
Lonner et al 2009 [18]	USA	Retro	1995–2005	≥2	S	67	NR	14.3 ± 2.3	48/7/7/0/0/5	51.5 ± 8	57 ± 21	10.5 ± 1.7	8
					H	33	NR	13.8 ± 1.9	20/5/3/0/1/4	51 ± 7	50 ± 13	12 ± 2	
Fu et al 2009 [19]	Japan	Retro	1996–2003	≥2	S	25	NR	14.2 ± 1.5	16/6/3/0/0/0	56 ± 8.7	48.7	NR	8
					H	54	NR	14.9 ± 2.1	41/11/2/0/0/0	58.7 ± 10.6	42.6	NR	
Helgeson et al 2010 [28]	USA	Retro	NR	≥2	S	37	NR	NR	NR	NR	NR	NR	6
					H	177	NR	NR	NR	NR	NR	NR	
Wu et al 2010 [29]	China	Retro	1997–2003	≥2	S	88	NR	14.3	NR	61.4	NR	8.5	8
					H	80	53/27	14.8	NR	60.8	NR	9.1	
Smucny et al 2011 [30]	USA	Prosp	After 2003	2	S	93	75/18	14.1 ± 1.9	54/22/13/4/0/0	58.6 ± 11.1	NR	NR	8
					H	61	47/14	14.4 ± 2.1	38/15/6/2/0/0	60.6 ± 9.6	NR	NR	
Sabharwal et al 2011 [17]	USA	Retro	1997–2009	1.5	S	21	63/11	14.5	43/13/9/0/8/1	54 ± 16.4	NR	NR	7
					H	53				59 ± 12.7	NR	NR	
Yang et al 2012 [31]	China	Retro Matched	2000–2006	2	S	21	NR	14.7 ± 1.2	21/0/0/0/0/0	53 ± 18	49.2 ± 14.8	9.2 ± 1.4	8
					H	21	NR	14.7 ± 1.5	21/0/0/0/0/0	55 ± 8	49.4 ± 14.9	9.0 ± 1.2	
Yilmaz et al 2012 [32]	USA	Retro Matched	2000–2004	2	S	35	28/7	14.7 ± 1.9	27/2/3/0/1/2	58.7 ± 9.3	46.6 ± 27.1	10.6 ± 1.2	8
					H	35	31/4	14.2 ± 1.6	24/1/3/0/5/2	55.5 ± 5.7	49.3 ± 28.1	10.1 ± 1.6	
Hwang et al 2012 [33]	USA	Retro	1995–2006	≥5	S	56	41/15	14.4 ± 2.4	38/14/4/0/0/0	53.4 ± 10.2	51 ± 18	10.3 ± 2	7
					H	71	63/8	14.1 ± 1.8	43/17/5/6/0/0	58.2 ± 14.6	51 ± 18	11.3 ± 1.9	
Crawford et al 2013 [34]	USA	Retro	2000–2009	≥2	S	34	27/7	15	34/0/0/0/0/0	50.5	52.22	11.7	8
					H	29	26/3	14	29/0/0/0/0/0	50.0	50.98	9.9	
Samdani et al 2013 [35]	USA	Retro	2001–2009	≥2	S	540	421/119	14.6 ± 2.1	NR	52.5 ± 14.4	44.4 ± 21.6	NR	6
					H	87	72/15	14.7 ± 2.1	NR	55.8 ± 13.2	40.1 ± 18.4	NR	
Sugarman et al 2013 [36]	USA	Retro	1999–2008	NR	S	29	23/6	15.0 ± 2.2	19/3/4/0/1/2	54.5 ± 7.4	NR	12.24 ± 1.55	8
					H	27	17/10	14.0 ± 2.4	15/1/6/0/4/1	58.7 ± 15.8	NR	11.65 ± 1.74	
Halanski et al 2013 [37]	USA	Retro	2008–2010	NR	S	9	5/4	16.1 ± 3.1	NR	54 ± 11	NR	10 ± 3	7
					H	73	60/13	13.8 ± 3.2	NR	57 ± 8	NR	12 ± 2	
Legarreta et al 2014 [38]	USA	Retro	2007–2010	2	S	25	25/0	14.6 ± 2.0	25/0/0/0/0/0	61.7 ± 10.2	NR	11.9 ± 0.7	8
					H	25	22/3	15.7 ± 2.4	25/0/0/0/0/0	58.6 ± 12.8	NR	7.2 ± 1.1	
Haber et al 2014 [39]	USA	RCT	2006–2008	≥2	S	19	17/2	13.5 ± 2	13/5/0/1/0/0	55 ± 6	25 ± 8	9 ± 1	8
					H	18	14/4	14.3 ± 2	13/4/1/0/0/0	58 ± 8	29 ± 8	9 ± 1	
Liu et al 2014 [40]	China	Retro	2003–2008	≥2	S	21	18/3	15.0 ± 2.4	21/0/0/0/0/0	45.4 ± 8.1	52 ± 14	7.8 ± 0.9	8
					H	21	19/2	15.2 ± 2.4	21/0/0/0/0/0	47.6 ± 9.0	49 ± 19	7.6 ± 0.8	

Retro indicates retrospective study; H = hybrid instrumentation group, NOS = Newcastle–Ottawa scale, NR = not reported, Prosp = prospective study, RCT = randomized controlled trial, S = pedicle screw group.

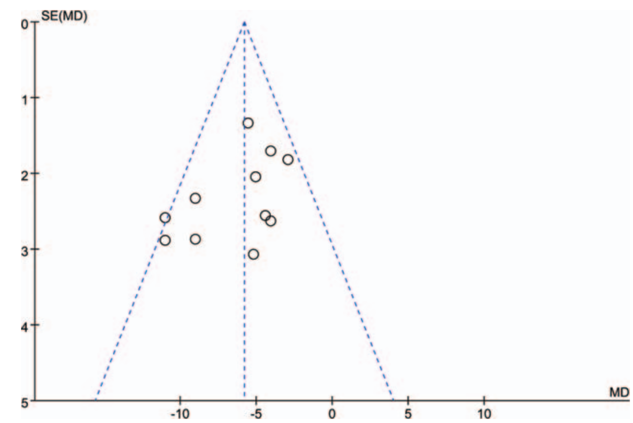

Figure 2. Funnel plot of major curve.

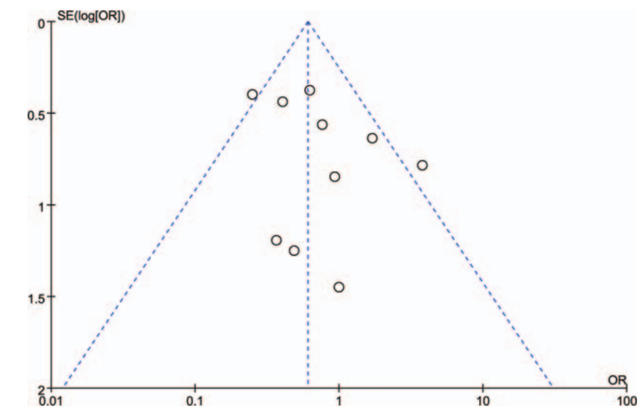

Figure 3. Funnel plot of complications.

when $I^2 < 50\%$ in the heterogeneity test, whereas a random effects model was used when $I^2 \geq 50\%$. Dichotomous variables, such as complications, are presented as odds ratios (OR) and 95% CI. Pooled mean difference and 95% CI are presented for continuous variables, such as Cobb angle of major curve.

The further classifications of complications and reoperations were analyzed using the SPSS 21.0 for Windows (SPSS Inc, Chicago, IL), χ^2 test was adopted for dichotomous variables, and a P value of <0.05 was considered statistically significant.

3. Results

3.1. Description of study

Four thousand sixty-seven potentially relevant studies were identified from electronic databases. Based on the inclusion and exclusion criteria, and quality assessment, 24 case-control studies with a total of 3042 AIS patients (1582 PS, 1460 HI) were finally included. [6,17–19,21–40] One RCT, 1 prospective study, and 22 retrospective studies were included. The flow diagram of study selection is shown in Fig. 1. The age at surgery, Cobb angle of major curve, fused levels were reasonably distributed, and the characteristics, baseline parameters of the included studies are shown in Table 1.

3.2. Quality and bias assessment

According to the NOS, 2 reviewers (ML, NL) rated the 24 control articles independently, and differences were resolved by consensus. Scores of the 24 studies were no less than 6 points, and the detailed quality assessment was shown in Table 1.

Publication bias was assessed with funnel plots. The funnel plot of Cobb angle of major curve is shown in Fig. 2, and the funnel plot of complications is shown in Fig. 3. All the included studies were symmetrically distributed on both the sides of the pooled proportion line.

3.3. Complications and reoperation rates

Pooled data on complications were available in 10 studies and composed of 2031 patients (1068 PS, 963 HI). The pooled result indicated that PS group had decreased complication rates (95% CI 0.42–0.87, $P = .007$; $I^2 = 38\%$; Fig. 4) compared with HI group. In addition, the risk of overall complications was further distributed into 5 aspects: implant-related complications, infection, radiographic complications, perioperative complications, and others. Screw malposition rate in PS group was the double of HI group (PS: 1.87%; HI: 0.93%), but decreased dislodged instrumentation (PS: 0.00%; HI: 0.93%, $P = .005$), pseudarthrosis (PS: 0.37%; HI: 1.35%, $P = .016$), and perioperative complications (PS: 1.97%; HI: 3.95%, $P = .008$) were found in PS group. The most common perioperative complications were respiratory complications, excessive blood loss, and urinary tract infection. The detailed descriptions of complications are shown in Table 2.

Pooled data on reoperations were extracted from 6 studies and composed of 1632 patients (969 PS, 663 HI). Decreased reoperations rates (95% CI 0.22–0.62, $P = .0001$; $I^2 = 0\%$; Fig. 5) were found in PS group. Furthermore, the reasons of

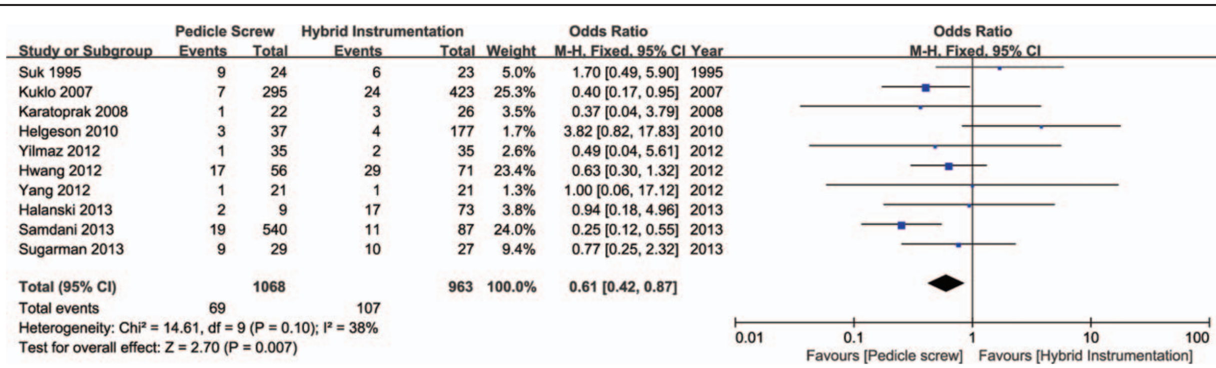

Figure 4. Forest plot of complications.

Table 2

The detailed descriptions of complications.

		PS group (n=1068)	HI group (n=963)	*P* value
Overall complications **n** (%)		69 (6.46%)	107 (11.11%)	<**.001**
Implant-related complications	Nerve root injury **n** (%)	4 (0.37%)	7 (0.73%)	.280
	Malposition **n** (%)	20 (1.87%)	9 (0.93%)	.075
	Prominent implant **n** (%)	3 (0.28%)	5 (0.52%)	.616
	Dislodged instrumentation **n** (%)	0 (0.00%)	9 (0.93%)	**.005**
Infection	Superficial infection **n** (%)	2 (0.19%)	2 (0.21%)	1.000
	Deep infection **n** (%)	9 (0.84%)	16 (1.66%)	.095
Radiographic complications	Pseudarthrosis **n** (%)	4 (0.37%)	13 (1.35%)	**.016**
	Proximal junctional kyphosis **n** (%)	3 (0.28%)	4 (0.42%)	.891
	Adding-on phenomenon **n** (%)	0 (0.00%)	3 (0.31%)	.212
	Shoulder imbalance **n** (%)	1 (0.09%)	0 (0.00%)	.257
Perioperative complications **n** (%)		21 (1.97%)	38 (3.95%)	**.008**
Other **n** (%)		2 (0.19%)	1 (0.10%)	1.000

Values are number of participants or percentage. A chi-squared test was used, and the bold *P* values <0.05 was considered statistically significant.

reoperation were analyzed. The most common reasons were deep infection, malposition, pseudarthrosis, prominent implant, and dislodged instrumentation. Decreased incidence of pseudarthrosis (PS: 0.41%; HI: 1.81%, $P = .005$), dislodged instrumentation (PS: 0.00%; HI: 1.06%, $P = .005$), and deep infection (PS: 0.93%; HI: 2.41%, $P = .016$) were found in PS group. The detailed descriptions of reoperations are shown in Table 3.

3.4. Radiographic outcomes of final follow-up

Cobb angle of major curve, thoracic kyphosis, and proximal junctional measurement of final follow-up were pooled and analyzed. Pooled data on Cobb angle of major curve were available in 11 studies and composed of 680 patients (308 PS, 372 HI), and PS group provided better coronal correction (95% CI −7.06 to −4.54, $P < .00001$; $I^2 = 34\%$; Fig. 6).

Data on thoracic kyphosis were extracted in 9 articles and composed of 734 patients (275 PS, 459 HI), and HI group was more powerful in restoring thoracic kyphosis (95%CI −7.88 to −3.70, $P < .00001$; $I^2 = 60\%$; Fig. 7) than PS group.

Pooled data on proximal junctional measurement were available in 5 studies and composed of 501 patients (173 PS, 328 HI), and no significant differences were found in proximal junctional measurement (95% CI −0.88 to 1.54, $P = .59$; $I^2 = 0\%$; Fig. 8) between the 2 constructs.

4. Discussion

This study, with a total of 3042 AIS patients included, is the largest study of comparing pedicle screw and hybrid instrumentations to date, and we first pooled and analyzed complications concerning the 2 constructs, to our limited knowledge. Decreased incidence rates of complications and reoperations, and better coronal correction were achieved using pedicle screw construct. In contrast, hybrid instrumentation provided better thoracic kyphosis restoring. However, almost all the included studies were retrospective and this caused huge loss of evidence for this study, and this was the major drawback of surgical treatments in AIS occurred.

Cao et al first published a meta-analysis in terms of the power of restoring thoracic kyphosis between pedicle screw and hybrid instrumentation in AIS patients. There were seven case-control studies included in his study, and better thoracic kyphosis restoring was found in hybrid instrumentation.[16] Complications and reoperations, which should be seriously considered, were not analyzed in his study. Therefore, a systematical and updated systematic review about complications between the 2 instrumentations in AIS was performed.

In our study, the risk of overall complications was 6.46% in PS group, and 11.11% in HI group. Similar results were reported by some other scholars. Reames et al utilized the Scoliosis Research Society Morbidity and Mortality database, and the total complication rates was 6.3%.[41] Stepanovich et al provided a review article and concluded that the risk of any operative or postoperative complication with the surgical correction in AIS was approximately 6%, a 1% to 2% risk of infection, and a 0.5% to 1% risk of neurological injury.[42]

The pooled result composed of 2031 patients indicated that pedicle screw construct achieved decreased complications ($P = .007$; $I^2 = 38\%$) compared with hybrid instrumentation. Screw malposition rate in PS group was the double of HI group (PS: 1.87%; HI: 0.93%) due to the increasingly implanted pedicle

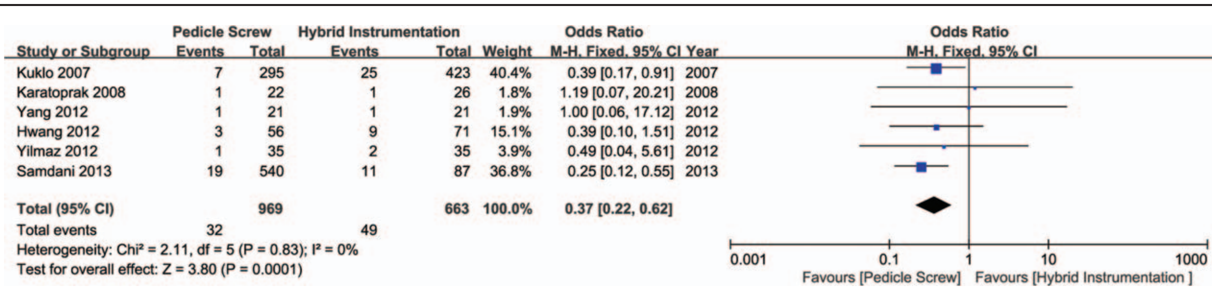

Figure 5. Forest plot of reoperations.

Table 3

The detailed descriptions of reoperations.

		PS group (n=969)	HI group (n=663)	*P* value
Total reoperations **n** (%)		32 (3.30%)	48 (7.24%)	**<.001**
Implant-related complications	Nerve root injury **n** (%)	0 (0.00%)	1 (0.15%)	.179
	Malposition **n** (%)	12 (1.24%)	4 (0.60%)	.201
	Prominent implant **n** (%)	3 (0.31%)	4 (0.60%)	.613
	Dislodged instrumentation **n** (%)	0 (0.00%)	7 (1.06%)	**.005**
Radiographic complications	Pseudarthrosis **n** (%)	4 (0.41%)	12 (1.81%)	**.005**
	Adding-on phenomenon **n** (%)	0 (0.00%)	3 (0.45%)	.132
	Shoulder imbalance **n** (%)	1 (0.10%)	0 (0.00%)	.307
Deep infection **n** (%)		9 (0.93%)	16 (2.41%)	**.016**
Decompensation **n** (%)		1 (0.10%)	0 (0.00%)	.307
Other **n** (%)		2 (0.21%)	1 (0.15%)	1.000

Values are number of participants or percentage. A chi-squared test was used, and the bold *P* values <0.05 was considered statistically significant.

screws. Decreased incidence rates of pseudarthrosis ($P=.016$), and dislodged instrumentation ($P=.005$) were found in pedicle screw construct. Compared with hooks, more stable and maintained fixation of pedicle screws was reported, which effectively reduced incidence of pseudarthrosis and instrumentation dislodgement.[43,44] The total perioperative complication rates in this study were 1.97% in PS group and 3.95% in HI group, and the most common perioperative complications were respiratory complications, excessive blood loss, and urinary tract infection. Yoshihara et al analyzed 43,983 pediatric patients with idiopathic scoliosis and reported that respiratory complication rate was the highest among in-hospital overall complication, and a total of 30.4% of patients received a blood transfusion.[45]

The reoperation rates were 3.30% in PS group and 7.24% in HI group, and the pooled data composed of 1632 patients also indicated that PS group achieved decreased reoperation rates ($P=.0001$; $I^2=0\%$). The most common reasons of reoperations were deep infection, malposition, pseudarthrosis, prominent implant, and dislodged instrumentation. Hicks et al conducted a systematic review with a total 1666 patients in regard to complications of pedicle screw fixation in scoliosis surgery, 0.83% patients had reoperation for misplaced or loose screws in his study.[11] Decreased incidence rates of pseudarthrosis ($P=.005$), dislodged instrumentation ($P=.005$), and deep infection ($P=.016$) were found in PS group, which were attributed to the stable and maintained fixation of pedicle screws.[43,44]

The pooled data indicated that PS group provided better coronal correction ($P<.00001$; $I^2=34\%$). Luhmann et al evaluated 101 moderate Lenke type 1A and 2A curve patterns and considered that pedicle screw could achieve better coronal correction (63% vs 54%),[9] and a similar result was reported by

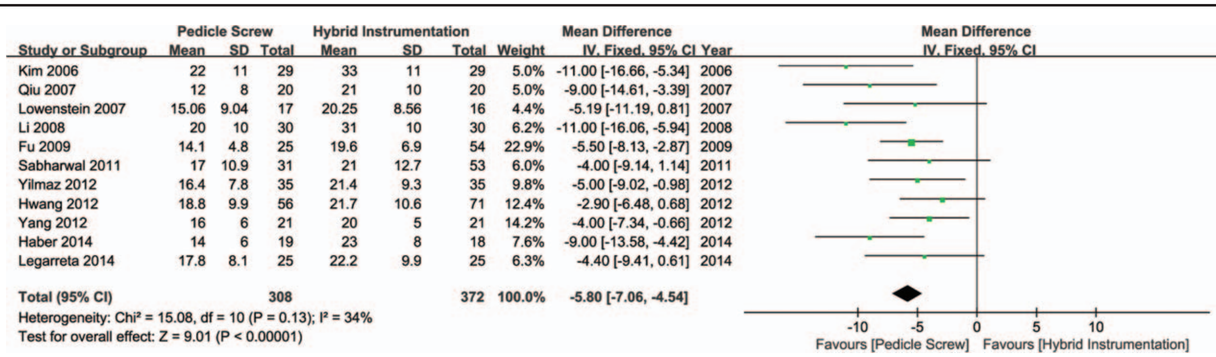

Figure 6. Forest plot of Cobb angle of major curve.

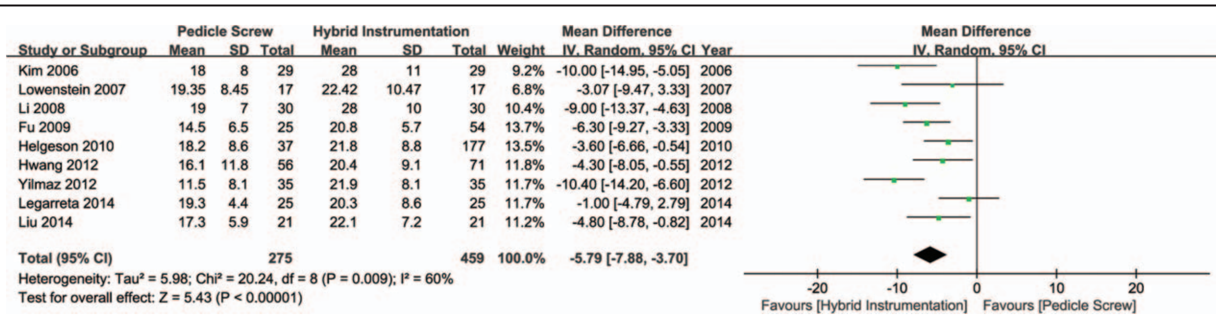

Figure 7. Forest plot of thoracic kyphosis.

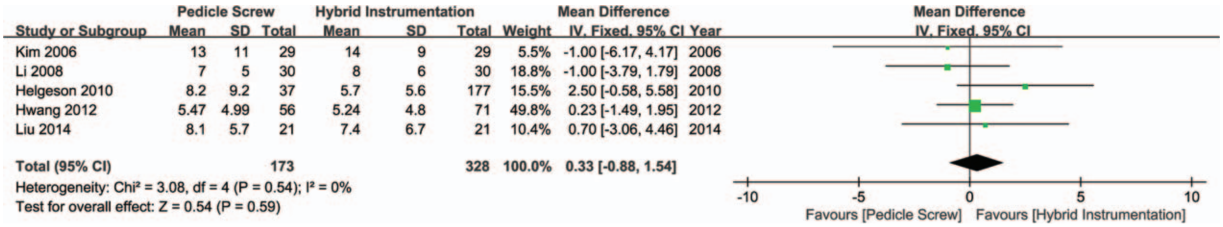

Figure 8. Forest plot of proximal junctional measurement.

Jaquith.[46] HI group was more powerful in restoring thoracic kyphosis ($P < .00001$; $I^2 = 60\%$), and it was consistent with Cao's conclusion.[16] Regrettably, the heterogeneity test of thoracic kyphosis revealed significant heterogeneity ($I^2 = 60\%$). As we know, AIS is a three-dimensional deformity. In most controlled studies, the baseline of the major curve was controlled at a moderate range from 40° to 70°. With the regulation of the coronal plane, it was difficult to avoid some disparities in the baseline of thoracic kyphosis due to the varieties of participants, and consequently in the outcome of thoracic kyphosis. No significant differences were found in proximal junctional measurement ($P = .59$; $I^2 = 0\%$) between the 2 constructs.

Some limitations should not be ignored in the study. First, almost all the included studies were retrospective in our study, this causes huge loss of evidence, and further RCTs should be performed. Unfortunately, RCTs were probably difficult to be performed since the Ethics committee will not approve a surgical RCT with a control group constituted of patients submitted to hybrid instrumentation. Second, complication is a broad concept that includes many aspects, such as in-hospital complication, long-term complication, and radiographic complication. The accuracy of complication rates was impacted by the various methodologies to report complication. Third, the heterogeneities of thoracic kyphosis existed, and it might be related to the varieties of participants.

5. Conclusion

Compared with hybrid instrumentation, pedicle screw construct provides better coronal correction but less thoracic kyphosis restoring, with decreased incidence of overall complications and reoperations in AIS patients. As regard to the pedicle screw construct, the most common reasons for reoperation are malposition, deep infection, pseudarthrosis, and prominent implant.

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