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Original Article

Volar locking plate versus percutaneous fixation for the treatment of distal radial fractures: a meta-analysis of randomized controlled trials

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Abstract: Background: Although operative fixation with a volar locking plate is becoming increasingly popular for treatment of distal radius fractures, it is not clear whether it is superior to other conventional treatment methods such as percutaneous fixation with Kirschner wires. The present meta-analysis compared the effects of internal fixation with volar locking plates and percutaneous fixation for the treatment of distal radius fractures. Methods: A literature search was performed without language restrictions and all randomized controlled studies comparing the effects of volar locking plates and percutaneous fixation for the treatment of distal radial fractures were included. Data of function scores, range of motion, grip strength, radiographic results, and complications were pooled and analyzed with a standard meta-analytical method. Results: Seven studies in seven publications were included. Pooled data indicated that there were no significant differences in Patient-Related Wrist Evaluation (PRWE) and Disabilities of the Arm, Shoulder, and Hand (DASH) scores between the two treatment methods postoperatively. Fixation with volar locking plates took significantly longer than percutaneous fixation. There was a significant difference in supination and grip strength favoring volar locking plate fixation at 3 and 6 months but not at ≥12 months, postoperatively. The final complication rates were similar in the two treatment groups. Conclusion: In the management of distal radius fractures, volar locking plate and percutaneous fixation yielded similar outcomes, while the former had the advantage of supination and grip strength in the early stage postoperatively. Percutaneous fixation was quicker to perform than volar locking plate fixation.

Keywords: Volar locking plate, distal radial fractures, percutaneous fixation, meta-analysis

Introduction

Operative fixation with a volar locking plate has becoming increasingly popular in the treatment of distal radius fractures [1, 2]. Many studies have indicated the advantages of the technique, and have shown good outcomes [3-5]. However, volar locking plate fixation is expensive and it can cause tendon problems and neurolysis, and a second implant-removal operation may be required [6-8]. It is not clear whether volar locking plate fixation is superior to other treatment methods. Recently, a few randomized controlled trials (RCTs) compared the effectiveness of volar locking plate versus minimally invasive and less expensive implants, such as percutaneous Kirschner wires, for the treatment of distal radial fractures. However, the small size or incomplete evaluation of these RCTs makes the results inconsistent. Recently, a systematic review [9] regarding volar locking plates and K-wire/pin fixation in the management of distal radius fractures has been published. Regrettably, the systematic review was not based on RCTs, which only provided level 2 evidence. Another two meta-analyses [10, 11] were performed based on RCTs, however, methodological flaws in the process of data management, make the results imprecise. Thus, whether surgical treatment of distal radial fractures with a volar locking plate improves clinical outcomes when compared with percutaneous Kirschner wires remains controversial.

To address this controversy, we try to provide level 1 evidence by pooling available data and

differentiated the evidence base on identified RCTs. The purpose of the present meta-analysis was to compare the differences in the functional and radiological outcomes between volar locking plates and percutaneous Kirschner wire fixation in patients with distal radius fractures. Furthermore, we stratified the patients aged ≥50 years who have tendency to have fragility fractures, as bone mineral density of the forearm remains stable up until the age of 50 years [12].

Methods

Search strategy

This meta-analysis was carried out following the guidelines of the PRISMA statement [13]. We performed a computerized search on March 16, 2013 and an updated literature search on October 18, 2014. The following search terms were used: "distal radius fractures" with the limitation of "randomized controlled trial" using PubMed (1949-2014), Ovid Medline (1946-2014), Medline In Process & Other Non-Indexed Citations (updated to October 18, 2014), Web of Knowledge and Embase (1966-2014). Cochrane Central Register of Controlled Trials (CENTRAL) (1948-2014). We placed no restrictions on the language of publication.

Reference lists of related review articles, all included publications, and previously published systematic reviews and meta-analyses were also reviewed to find additional eligible studies. Two authors (LS and MW) screened the titles and abstracts according to the eligibility criteria. The full texts were read when the studies met the inclusion criteria. Disagreements were resolved by discussion between the authors. If a consensus could not be reached, a third investigator (JD) made the final decision. The Jadad scale was used to evaluate the quality of included RCTs, with a score of <3 considered low quality [14].

Inclusion and exclusion criteria

The search results were screened on the basis of the following inclusion criteria: (a) randomized controlled studies on patients with distal radius fractures; and (b) comparison of volar locking plate versus percutaneous fixation. Exclusion criteria included: (a) non-randomized controlled trials; (b) trials focused on pediatric fractures; and (c) patients with distal radius fractures who presented >3 weeks after injury.

Data extraction

The primary outcome of our analysis was functional outcome, measured using the Patient-Related Wrist Evaluation (PRWE) and Disabilities of the Arm, Shoulder, and Hand (DASH) scores. The secondary outcomes were range of motion (ROM) and radiological outcome. Data of operation time and complications were collected. We sent an email to every corresponding author to obtain the original data. When there was inconsistency between the published and original data, the latter were used. When original data were not available, or if means were presented without standard deviations (SDs), the SDs were calculated from the *P* value or confidence interval (CI), following the guidance of the Cochrane Handbook for Systematic Reviews of Interventions [15]. In some cases, the published reports of clinical trials only reported the median and range, and the mean and SDs were estimated using the formulas founded by Hozo et al. [16].

Statistical analysis

We performed all meta-analyses using the Stata/SE 10.0 program. For the meta-analysis of continuous variables using the same scales, the weighted mean difference (WMD) with a 95% CI was used. For dichotomous variables, the relative treatment effect was presented as relative risk (RR) with a 95% CI. The assessment for statistical heterogeneity was investigated using the χ^2 test and quantified using the I^2 statistic. A random-effect model was used in the present meta-analysis based on the fact that different fixation plates and methods of percutaneous fixation method were used, and the test for heterogeneity had low statistical power. If possible data were available, we performed independent analysis regarding the patients aged ≥50 years. $P<0.05$ was considered statistically significant.

Sensitivity analysis and assessment of publication bias

A sensitivity analysis was performed by detecting the effect of each individual study on the pooled effect size. Funnel plots and Egger's test were used to assess potential publication

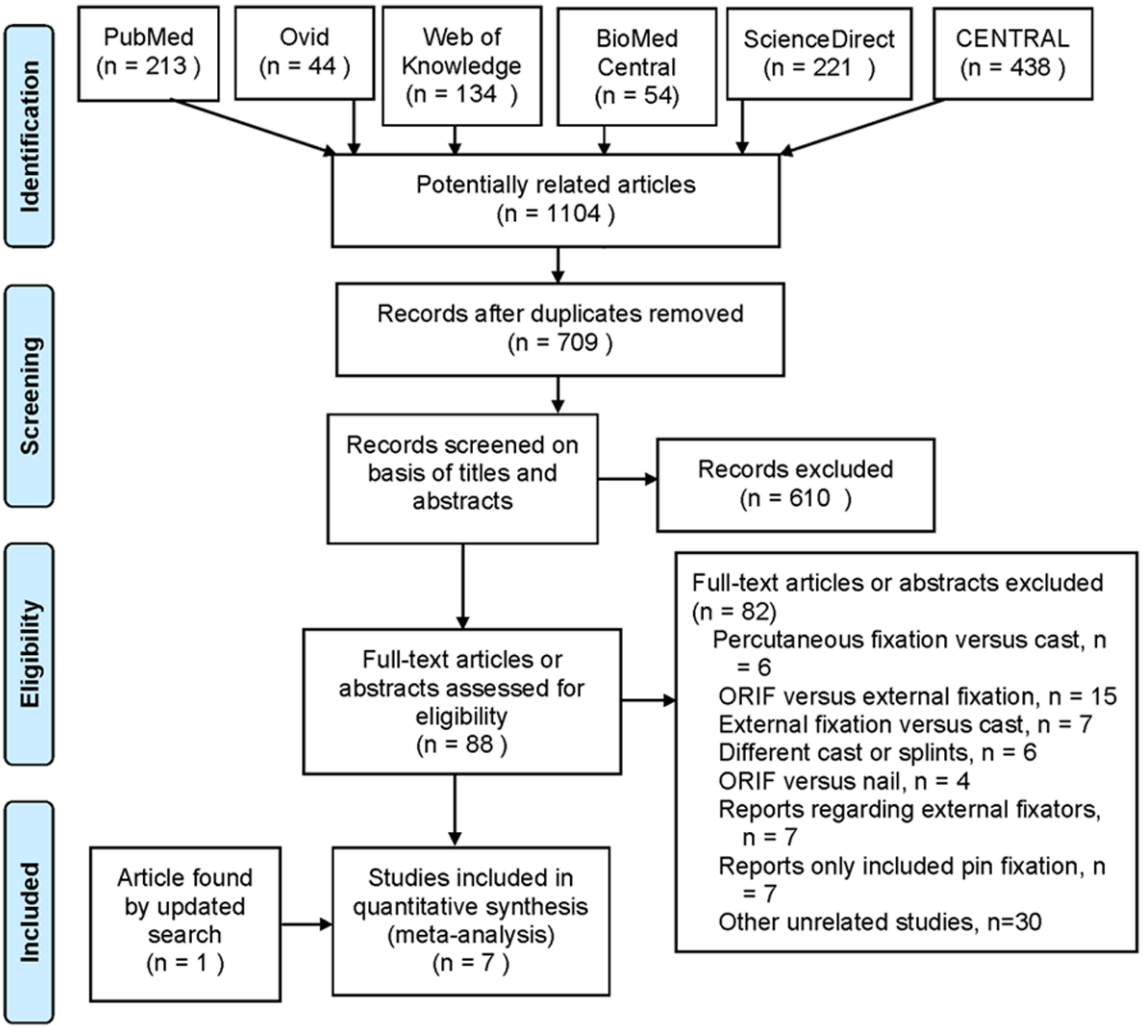


Figure 1. Flowchart of the present meta-analysis. CENTRAL, Cochrane Central Register of Controlled Trials.

bias. A further analysis was conducted using the trim and fill method, when possible publication bias was detected.

Results

Selected studies and characteristics

As shown in **Figure 1**, a total of 709 potentially relevant studies were identified and screened in the original search, and only six RCTs met the inclusion criteria. An additional study [17] was identified in the updated search, thus, seven publications were selected for the meta-analysis. One RCT [18] was excluded from our analysis because it was restricted to patients with displaced distal radius fractures who presented within 3-6 weeks from injury. The basic characteristics of the included studies are shown in **Table 1**. The quality of each article was graded from 2 to 4 according to the Jadad quality score [14]. A total of 874 patients were included in this analysis. The corresponding authors of six publications [17, 19-23], but not the other [24] responded to our email and original data were provided from five trials [19-23]. Because of the obvious nature of the intervention, no trials were double-blind.

Effects of volar locking plate versus percutaneous fixation on functional outcome

Table 2 shows the PRWE scores for the two study groups at 3, 6 and ≥12 months. There was no evidence for a significant difference in PRWE scores between the two treatment methods at any time point (all $P>0.05$). The pooled data of DASH scores demonstrated that there

Table 1. Baseline characteristics of the included RCTs

Author/ year	Age (year)	No. of patients, (IF/PF)	Female patients (IF/PF)	Classification of fractures	IF	PF	Follow-up time (month)	Outcomes measured	Jadad score
Costa et al. 2014	>18	231/230	194/191	AO types A1, A2, A3, B1, B2, B3 and C1, C2, C3	Volar locking plates	Size and number of wires, insertion technique, and configuration of wires were decided by the surgeon. A plaster cast was applied.	12	PRWE score, DASH score and EQ-5D, surgical time, rate of perioperative antibiotic use, complications.	4
Goehre et al. 2014	65-94	21/19	N/A	AO types A2, A3, and C1	LCP Distal Radius System 2.4	1.6-2.0 mm wires via an intrafocal Kapandji, ranstyloidal Willenegger, or combined technique.	12	DASH, PRWE and Castaing scores, operation time, duration of postoperative immobilization, radiological evaluation, ROM, grip strength, return to activities of daily living, and complications.	2
Karantana et al. 2013	18-73	66/64	47/50	AO fracture type A3, C2, C3.	Volar locking plates	Conventional treatment with closed reduction and percutaneous Kirschner wire fixation with or without external fixation.	12	Hand Health Profile section of the Patient Evaluation Measure (PEM) and the Quick DASH, EuroQol-5D self administered Questionnaire, ROM, grip strength, radiographic results, resumed driving, returning to work and complications.	3
McFadyen et al. 2011	18-80	27/29	15/18	AO fracture type A1, A2, A3.	IF with use of a volar locking plate	Three 1.6-mm percutaneous pins. Two pins were placed in the styloid process, one dorsally and one volarly, and one pin from the dorsal aspect of the mostulnar corner of the radius.	6	The Gartland and Werley score, the Quick DASH, radiographic results and complications.	3
Hollevoet et al. 2011	52-85	20/20	16/20	Colles' fractures	a 2.4-mm LCP Synthes volar locking plates	Two or three 1.6 mm K-wires were used to stabilize the fracture.	12-26	DASH score, ROM, Grip strength, operation time, radiographic results and complications.	3
Marcheix et al. 2010	>50	50/53	38/48	AO fracture type A2, A3, C2, C3.	Volar locking plates	Four Kirschner wires, 1.8 or 2.0 mm were used.	6	The Herzberg score, DASH score, operation time, ROM, Grip strength, radiographic results and complications.	3
Rozental et al. 2009	19-79	23/21	16/17	AO fracture type A2, A3, C1, C2.	VLS and DVR plates	Three 1.6 mm K-wires were used. Two patients with severe osteoporosis and extensive extra-articular comminution required external fixation.	12	DASH score, ROM, grip and pinch strength, digital motion to palm, patient satisfaction, return to work/activities, radiographic results and complications.	3

IF, internal fixation with volar locking plates; PF, percutaneous fixation; DASH, Disabilities of the Arm, Shoulder and Hand; PRWE, Patient-Rated Wrist Evaluation; ROM, range of motion.

was no significant difference between volar locking plate and percutaneous fixation in the treatment of distal radius fractures at 3, 6 and 12 months, postoperatively (all $P>0.05$) (**Table 2**).

Independent analysis compared internal and percutaneous fixation in patients aged ≥50 years. For PRWE scores, data were only available from ≥12 months postoperatively. Pooled analysis showed that there was no significant difference in PRWE scores between the two treatment groups (RR=-0.543, 95% CI -2.891 to 1.806, $P=0.651$). The pooled data of DASH scores showed that there were no significant differences between volar locking plate and percutaneous fixation groups at any time point postoperatively (**Table 3**).

Effects of volar locking plate versus percutaneous fixation on operation time, wrist and forearm range of motion and grip strength

Four of the seven included studies reported operation time data. Meta-analysis demonstrated that internal fixation with volar locking

Table 2. Comparison of IF with volar locking plates and PF regarding PRWE, DASH and grip strength

Parameters	Time (mo)	No. of studies	Participants		WMD	95% CI	*P* value	Favors
			IF	PF				
PRWE	3	2	236	231	-2.69	-6.56 to 1.17	0.17	
	6	2	227	227	-1.82	-5.05 to 1.41	0.27	
	12	2	225	230	-0.54	-2.89 to 1.81	0.65	
DASH	3	4	110	112	-6.19	-12.75 to 0.37	0.06	
	6	2	71	72	-6.31	-16.57 to 3.94	0.23	
	12	4	255	259	-1.53	-3.88 to 0.81	0.20	
Grip strength	3	5	175	176	10.81	3.77 to 17.86	<0.01	IF
	6	3	137	136	12.05	3.05 to 21.05	<0.01	IF
	12	4	126	119	3.03	-6.87 to 12.93	0.55	

IF, internal fixation; PF, percutaneous fixation; WMD, Weighted mean difference; CI, confidence interval; PRWE, Patient-Rated Wrist Evaluation; DASH, Disabilities of the Arm, Shoulder and Hand.

Table 3. Comparison of IF with volar locking plates and PF regarding outcomes of PRWE, DASH and grip strength in patients aged ≥50 years

Parameters	Time (mo)	No. of studies	Participants		WMD	95% CI	*P* value	Favors
			IF	PF				
PRWE	12	2	178	176	-0.54	-2.89 to1.81	0.65	
DASH	3	3	91	87	-3.48	-8.96 to1.99	0.21	
	6	2	72	71	6.31	-16.57 to 0.94	0.23	
	12	2	37	37	0.04	-2.31 to 2.39	0.98	
Grip strength	3	3	91	87	7.67	1.10 to14.24	0.02	IF
	6	2	72	71	7.63	0.37 to 14.90	0.04	IF
	12	2	34	37	-2.94	-13.87 to 7.99	0.60	

CI, confidence interval; DASH: Disabilities of the Arm, Shoulder, and Hand; IF, internal fixation; PF, percutaneous fixation; PRWE, Patient-Rated Wrist Evaluation; WMD, Weighted mean difference.

plates took significantly longer than percutaneous fixation (RR=22.0, 95% CI: 18.648-25.352, *P*<0.001) (**Figure 2**).

Pooled data of wrist and forearm ROM were available from 3-6 of the seven studies. Only Goehre et al. [24] reported postoperative radial and ulnar deviation data at 6 months, so we were not able to perform a pooled analysis on postoperative radial and ulnar deviation at that time. There was a significant difference in supination favoring volar locking plate fixation at 3 and 6 months but not at ≥12 months postoperatively. For any other ROM variables, there were no significant differences (all *P*>0.05) in treatment effect at 3, 6 and ≥12 months between these two fixation methods (**Table 4**). Independent comparative analysis of internal and percutaneous fixation in patients aged ≥50 years demonstrated the same results (**Table 5**).

Pooling of grip strength data was possible across 3 to 5 of the seven studies at different times. Meta-analysis of grip strength demonstrated that fixation with volar locking plates was superior to percutaneous fixation at 3 and 6 months postoperatively. However, at ≥12 months, the grip strength was similar between the two treatment methods (**Table 2**). For patients aged ≥50 years, independent comparative analysis of volar locking plate and percutaneous fixation demonstrated similar results (**Table 3**).

Effects of volar locking plate versus percutaneous fixation on radiographic parameters

The radiographic parameters including volar tilt, radial height and radial inclination were pooled and analyzed. Radiological outcomes comparing volar locking plate with percutaneous fixation at different times postoperatively are shown in **Table 6**. Pooled data across 2 or 3 studies showed that there were no significant differences between the two treatment groups immediately post-operation, and at 6 and ≥12 months postoperatively (all *P*>0.05). For patients aged ≥50 years, there were no radiographic data available, so we were not able to perform an independent analysis.

Effects of volar locking plate and percutaneous fixation on final complications

The seven included trials reported a total of 874 patients and provided information on over-

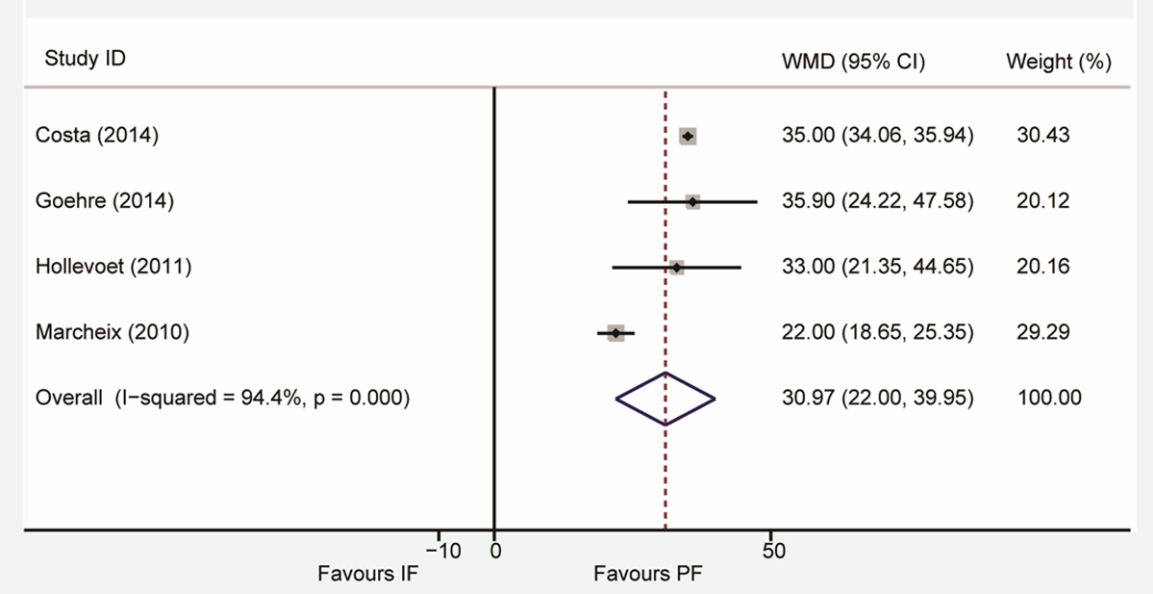


Figure 2. Forest plot for estimation of operation time for internal fixation with volar locking plates versus percutaneous fixation. IF, internal fixation; PF, percutaneous fixation.

Table 4. Comparison of IF with volar locking plates and PF regarding ROM

Time (month)	ROM results	No. of studies	Participants		WMD	95% CI	*P* value	Favors
			IF	PF				
3	Supination	6	183	183	4.75	1.39 to 8.12	0.01	IF
	Pronation	6	183	183	0.51	-2.33 to 3.34	0.73	
	Extension	6	183	183	2.34	-0.77 to 5.44	0.14	
	Flexion	6	183	183	3.17	-0.30 to 6.63	0.07	
	Radial deviation	3	61	59	0.34	-2.31 to 3.00	0.80	
	Ulnar deviation	3	61	59	1.93	-2.29 to 6.15	0.37	
6	Supination	3	74	75	8.70	4.48 to 12.93	<0.001	IF
	Pronation	3	74	75	-0.64	-2.60 to 1.33	0.53	
	Extension	3	74	75	2.24	-0.97 to 5.45	0.17	
	Flexion	3	74	75	4.26	-0.25 to 8.76	0.06	
≥12	Supination	4	123	118	0.74	-1.13 to 2.61	0.44	
	Pronation	4	123	118	-0.94	-2.34 to 0.47	0.19	
	Extension	4	123	118	0.84	-2.42 to 4.09	0.61	
	Flexion	4	123	118	-0.55	-4.41 to 3.32	0.78	
	Radial deviation	3	56	54	1.04	-3.52 to 5.60	0.66	
	Ulnar deviation	3	56	54	3.56	-2.333 to 9.454	0.24	

CI, confidence interval; IF, internal fixation; PF, percutaneous fixation; ROM, range of motion; WMD, weighted mean difference.

all complications at final follow-up. Meta-analysis indicated that the final complications with volar locking plate did not differ significantly from those with percutaneous fixation (RR=0.610, 95% CI: 0.364-1.022, *P*=0.06). Further analysis indicated that major complications detected no significant difference between the two groups (RR=0.708, 95% CI: 0.389-1.290, *P*=0.259). There were significantly fewer minor complications in the patients treated with volar locking plate than percutaneous fixation (RR=0.561, 95% CI: 0.351-0.895 *P*=0.015) (**Figure 3**). We performed an independent meta-analysis regarding the incidence of

Table 5. Comparison of IF with volar locking plates and PF regarding ROM in patients aged ≥50 years

Time (month)	ROM results	No. of studies	Participants		WMD	95% CI	*P* value	Favors
			PF	IF				
3	Supination	3	91	90	6.51	1.38 to 11.65	0.01	IF
	Pronation	3	91	90	0.09	-4.06 to 4.25	0.97	
	Extension	3	91	90	1.84	-1.93 to 5.60	0.34	
	Flexion	3	91	90	4.70	-0.48 to 9.89	0.08	
	Radial deviation	2	38	38	-0.13	-3.13 to 2.88	0.93	
	Ulnar deviation	2	38	38	-0.71	-5.27 to 3.85	0.76	
6	Supination	2	72	71	8.70	4.48 to 12.93	<0.001	IF
	Pronation	2	72	71	-0.64	-2.60 to 1.33	0.53	
	Extension	2	72	71	3.34	-0.86 to 7.55	0.12	
	Flexion	2	72	71	4.92	-0.03 to 9.86	0.05	
≥12	Supination	2	33	34	1.82	-1.57 to 5.21	0.29	
	Pronation	2	33	34	-0.16	-3.32 to 3.00	0.92	
	Extension	2	33	34	2.96	-2.60 to 8.52	0.30	
	Flexion	2	33	34	-0.03	-10.77 to 10.71	1.00	
	Radial deviation	2	33	34	-0.84	-4.40 to 2.72	0.65	
	Ulnar deviation	2	33	34	0.32	-3.52 to 4.16	0.87	

CI, confidence interval; IF, internal fixation; PF, percutaneous fixation; ROM, range of motion; WMD, weighted mean difference.

Table 6. Comparison of IF with volar locking plates and PF regarding radiographic results

Time	Parameters	No. of studies	Participants		WMD	95% CI	*P* value	Favors
			IF	PF				
Immediately post-operation	Volar tilt	2	77	82	1.61	-9.37 to 12.58	0.77	
	Radial height	3	100	103	-0.17	-1.28 to 0.93	0.76	
	Radial inclination	3	100	103	0.26	-0.61 to 1.13	0.55	
6 month	Volar tilt	3	98	101	2.23	-9.84 to 14.30	0.72	
	Radial height	2	77	82	-0.68	-2.14 to 0.79	0.36	
	Radial inclination	2	77	82	1.01	-2.91 to 4.93	0.61	
12 month	Volar tilt	2	89	85	1.99	-5.85 to 9.83	0.62	
	Radial height	2	89	85	0.27	-0.08 to 0.63	0.13	
	Radial inclination	2	89	85	0.70	-0.45 to 1.85	0.23	

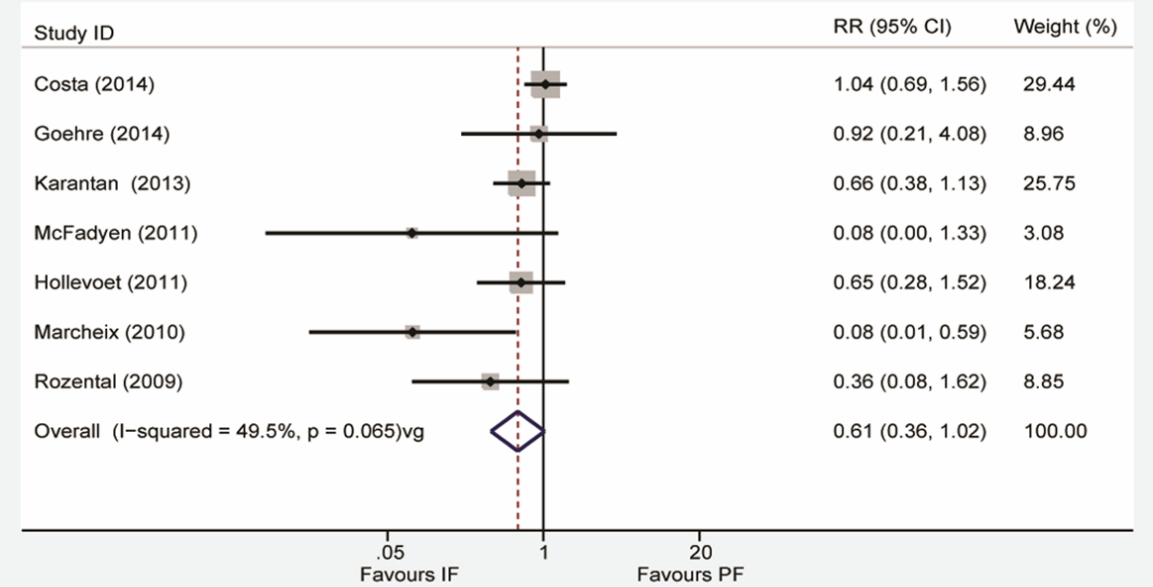
IF, internal fixation; PF, percutaneous fixation; WMD, weighted mean difference; CI, confidence interval.

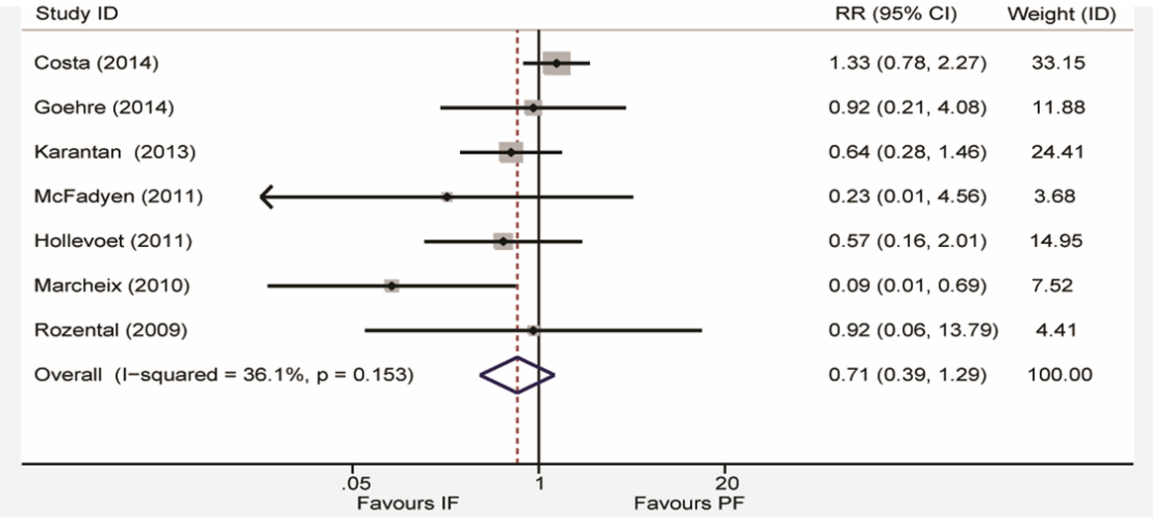
second surgical intervention, and the need for further surgery was similar in both treatment groups (RR=1.201, 95% CI: 0.361-3.990, *P*=0.765) (**Figure 4**). Independent analysis of patients aged ≥50 years demonstrated that there was no significant difference between internal and percutaneous fixation regarding final complications (RR=0.440, 95% CI: 0.121-1.601, *P*=0.075), minor and major complications (RR=0.516, 95% CI: 0.155-1.713, *P*=0.280; RR=0.427, 95% CI: 0.123-1.487, *P*=0.181) (**Figure 5**), and further surgery (RR=5.625, 95% CI: 0.411-76.976, *P*=0.196) (**Figure 4**).

Sensitivity and publication bias analysis

We selected complications data for sensitivity and publication bias analysis, since all of the studies had such data. Sensitivity analysis was evaluated by detecting the influence of any individual study on the overall RR. No individual study affected the overall RR dominance, because omission of any single study did not make a large difference (**Figure 6**).

Begg's funnel plot and Egger's test evaluated the publication bias. The shape of the funnel plot showed symmetry (*P*=0.072), but the


Study ID
RR (95% CI)
Weight (%)
Costa (2014)
1.04 (0.69, 1.56)
29.44
Goehre (2014)
0.92 (0.21, 4.08)
8.96
Karantan (2013)
0.66 (0.38, 1.13)
25.75
McFadyen (2011)
0.08 (0.00, 1.33)
3.08
Hollevoet (2011)
0.65 (0.28, 1.52)
18.24
Marcheix (2010)
0.08 (0.01, 0.59)
5.68
Rozental (2009)
0.36 (0.08, 1.62)
8.85
Overall (I−squared = 49.5%, p = 0.065)vg
0.61 (0.36, 1.02)
100.00
.05
1
20
Favours IF
Favours PF


Study ID
RR (95% CI)
Weight (ID)
Costa (2014)
1.33 (0.78, 2.27)
33.15
Goehre (2014)
0.92 (0.21, 4.08)
11.88
Karantan (2013)
0.64 (0.28, 1.46)
24.41
McFadyen (2011)
0.23 (0.01, 4.56)
3.68
Hollevoet (2011)
0.57 (0.16, 2.01)
14.95
Marcheix (2010)
0.09 (0.01, 0.69)
7.52
Rozental (2009)
0.92 (0.06, 13.79)
4.41
Overall (I−squared = 36.1%, p = 0.153)
0.71 (0.39, 1.29)
100.00
.05
1
20
Favours IF
Favours PF

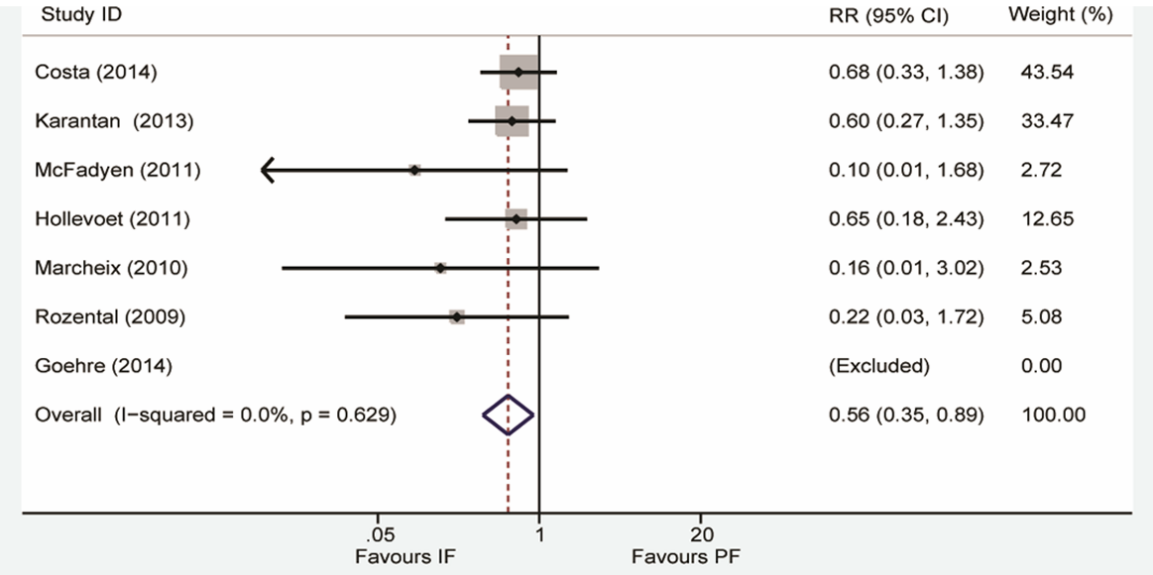

Study ID
RR (95% CI)
Weight (%)
Costa (2014)
0.68 (0.33, 1.38)
43.54
Karantan (2013)
0.60 (0.27, 1.35)
33.47
McFadyen (2011)
0.10 (0.01, 1.68)
2.72
Hollevoet (2011)
0.65 (0.18, 2.43)
12.65
Marcheix (2010)
0.16 (0.01, 3.02)
2.53
Rozental (2009)
0.22 (0.03, 1.72)
5.08
Goehre (2014)
(Excluded)
0.00
Overall (I−squared = 0.0%, p = 0.629)
0.56 (0.35, 0.89)
100.00
.05
1
20
Favours IF
Favours PF

Figure 3. Forest plot for RR estimate for internal fixation with volar locking plates versus percutaneous fixation. Upper graph, assessment of overall complication rate. Middle graph, assessment of major complication rate. Bottom graph, assessment of minor complication rate. IF, internal fixation; PF, percutaneous fixation.

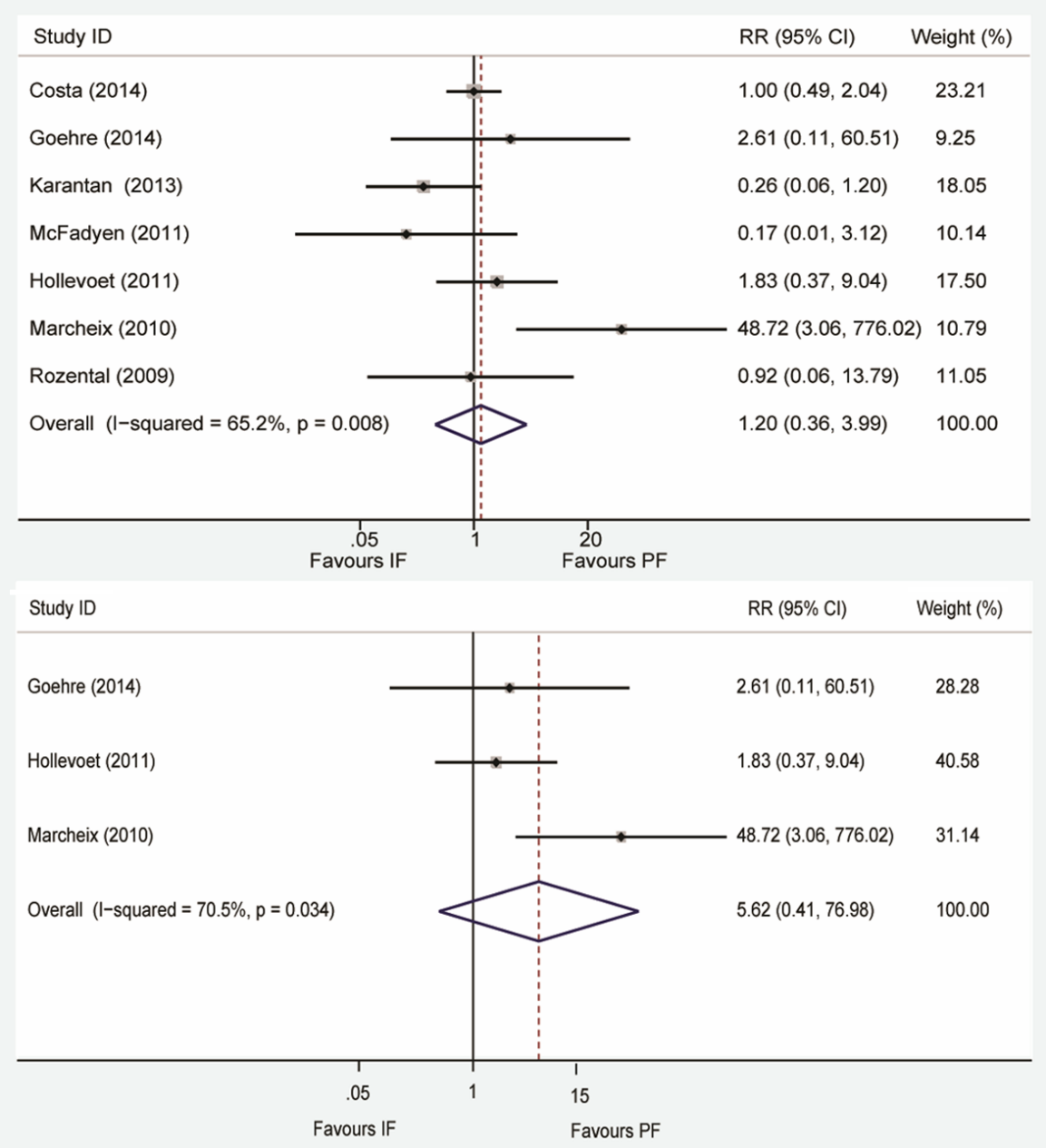


Figure 4. Forest plot for estimation of further surgery rate. Upper graph, assessment of further surgery rate in internal fixation with volar locking plates versus percutaneous fixation. Bottom graph, independent assessment of further surgery rate in patients aged ≥50 years. IF, internal fixation; PF, percutaneous fixation.

Egger's test suggested a possible publication bias (P=0.023). We conducted a trim and fill method to investigate the publication bias further. The pooled analysis incorporating the hypothetical studies continued to show that the final complications with volar locking plate in comparison with percutaneous fixation were not significant (RR=0.621, 95% CI: 0.379-1.018, P=0.059) (**Figure 6**).

Discussion

The studies included in our meta-analysis adopted a variety of outcome variables to eval-

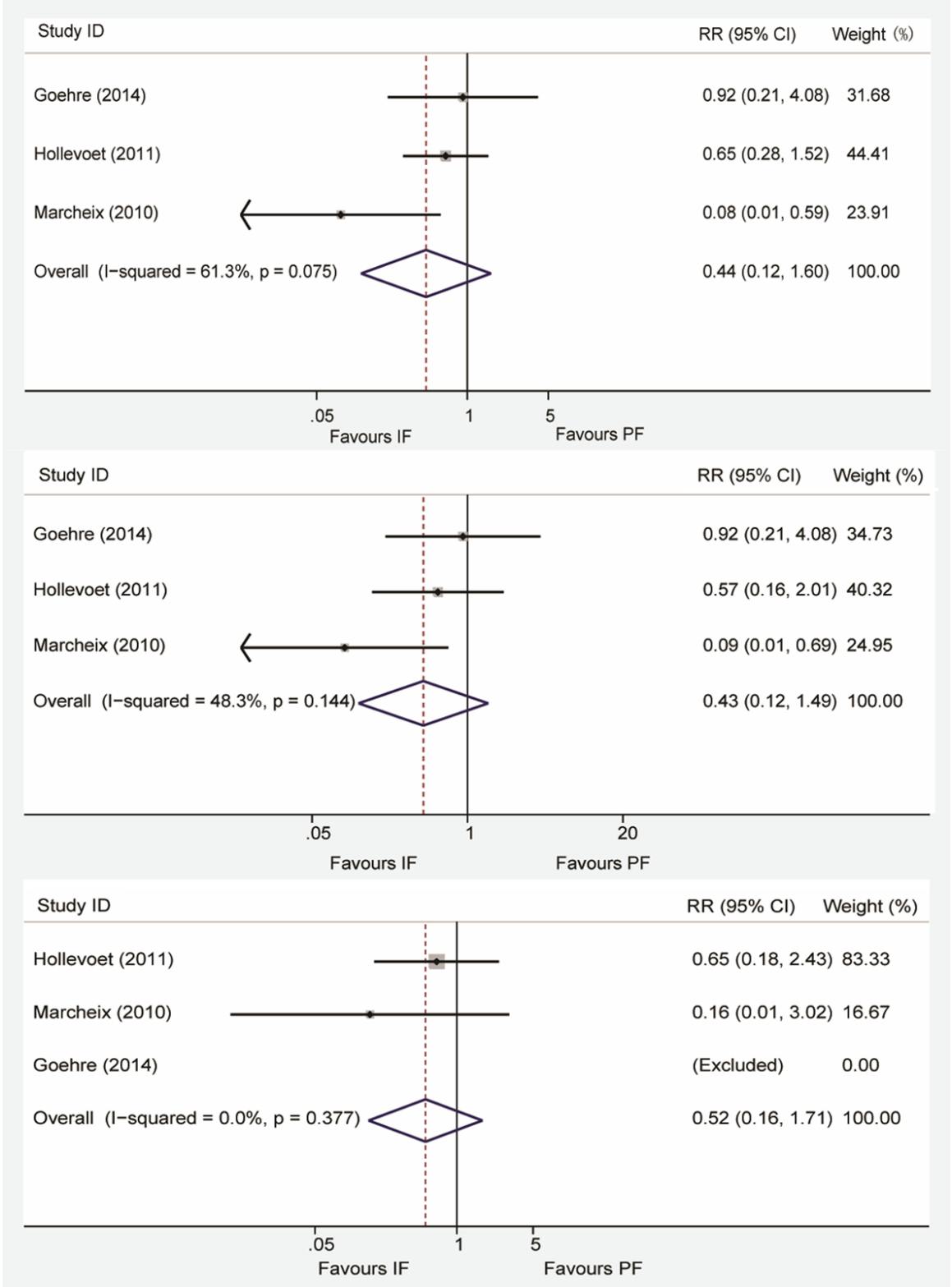


Figure 5. Forest plot for independent analysis of internal fixation with volar locking plates versus percutaneous fixation in patients aged ≥50 years. Upper graph, assessment of overall complication rate. Middle graph, assessment of major complication rate. Bottom graph, assessment of minor complication rate. IF, internal fixation; PF, percutaneous fixation.

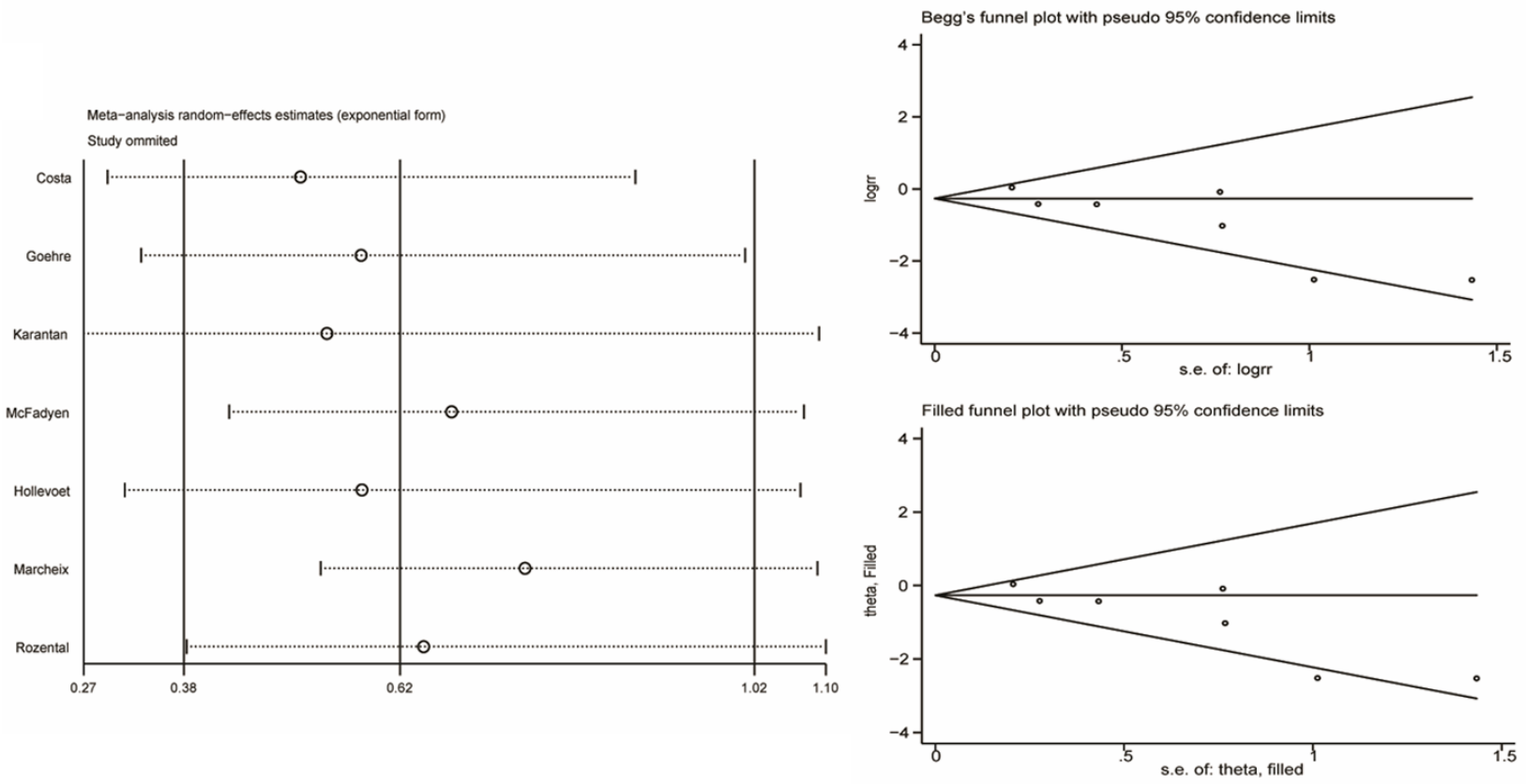


Figure 6. Sensitivity and publication bias analysis. Left graph: influence of individual studies on summary RR. Right graph: publication bias analysis. Upper graph: Begg's funnel plot with pseudo 95% CIs. Bottom graph: Filled funnel plot with pseudo 95% CI. WMD, weighted mean difference; S.E., standard error.

uate the effects of volar locking plate and percutaneous fixation for treatment of distal radial fractures. Patient-reported, clinical and radiographic outcome measures were not performed in all of the RCTs and postoperative outcome was not measured at the same time points, such as 6 weeks, 6 months and 1 year. This variability suggested that, to make a precise and full evaluation of the outcomes of treating distal radius fractures, a well-designed protocol with completed evaluation parameters needs to be established in advance.

Our meta-analysis showed that in treating distal radial fractures, volar locking plate and percutaneous fixation yielded similar outcomes. Although volar locking plates have the advantage of supination and grip strength at 3 and 6 months postoperatively, this was not reflected in the functional outcome. In contrast, percutaneous fixation is quicker to perform than volar locking plate fixation. Over the past decade, there has been a shift in the surgical approach for treatment of distal radial fractures in favor of open reduction and internal fixation, to achieve anatomical reconstruction of the fractured bone. By pooling and analyzing the original data provided by the corresponding author, our results suggested that if early grip strength and supination rehabilitation are important, volar locking plate fixation is an alternative method. Otherwise, percutaneous fixation is an ideal treatment. In contrast, the results of grip strength were not presented although the authors mentioned that the data on grip strength were collected in one recently published meta-analysis [11], and the grip strength data were analyzed with incorrect raw data in the other meta-analysis [10]. We believe that our results are correct and precise.

Our pooled data indicated that overall and major complication rates were similar and only the minor complication rate was lower in the volar locking plate fixation group compared with percutaneous fixation group. It could be postulated that most of the minor complications were resolved without surgery, because the incidence of second surgical intervention was similar in both treatment groups.

Even though it was reported that anatomical function can be restored and maintained with volar locking plates in elderly patients with osteoporosis [25], our analysis indicated that the PRWE and DASH scores did not differ between internal and percutaneous treatment groups in patients aged ≥50 years. Our results were similar to some aspects of Arora's randomized controlled study [26], which compared volar locking plate fixation with another conventional method, closed reduction and cast immobilization for displaced and unstable distal radial fractures in patients aged ≥65 years. They found that there were no significant differences between these two treatment groups at 6 and 12 months.

The present meta-analysis had some limitations. First, it is reasonable that there was a high correlation between anatomical and functional outcomes in young, active, and high-functioning patients [27, 28]. Even though pooled analysis regarding patients aged ≥50 years was possible based on data from three of the included studies, there was a wide age range in the other four studies. Only Costa et al. [17] analyzed functional data in patients with sub-groups age <50 or ≥50 years, so we were not able to perform a sub-group or independent analysis to compare the effects of volar locking plates and percutaneous fixation regarding patients aged <50 years. Second, It was reported that the functional outcome after distal radial fractures treated with a volar locking plate was significantly associated with fracture type [29]. There was a wide range of fracture types in our meta-analysis, but we were not able to reveal differences in fracture type-specific effects between volar locking plates and percutaneous fixation due to the limited number of trials. No trials performed subgroup analysis regarding fracture types. Finally, there is a cost implication to using volar locking plates. However, only Tubeuf et al. [30] presented an economic evaluation and indicated that, compared with volar locking plate, percutaneous fixation is a cost-saving intervention, with similar health benefits to those of the recent study of Costa et al. [17]; therefore, we were not able to acquire evidence regarding this factor.

In conclusion, based on the data from available clinical studies, volar locking plate fixation is similar to percutaneous fixation for the treatment of distal radius fractures and percutaneous fixation is quicker to perform than volar locking plate fixation. We suggest further RCTs could compare the effects of volar locking plate with percutaneous fixation in patients with

stratified analysis regarding age and fracture type, paralleled with cost-effectiveness analysis.

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Disclosure of conflict of interest

None.

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