Original Article

Volar Locking Plate versus External Fixation for Distal Radius Fractures: A Meta-analysis of Randomized Controlled Trials

Abstract

Background: Volar locking plate (VP) and external fixation (EF) are the two most commonly used methods for treating distal radius fractures. The aim of this study was to identify which of the two treatments leads to better outcomes (clinically and radiographically) with fewer complications. **Materials and Methods:** A metaanalysis was performed. All available randomized controlled trials (RCTs) which compared the clinical results of VP to EF were obtained and the reported means and standard deviations were extracted to perform data synthesis. **Results:** A total of 9 published RCTs with 776 patients fulfilled all inclusion criteria. Data analysis revealed that VP gives better clinical results in the early postoperative period in terms of disabilities of the arm, shoulder, and hand (DASH) scores (3 and 6 months), grip strength (3 months), flexion, extension, and supination (3 months). VP is also advantageous over EF regarding the DASH scores, maintenance of ulnar variance, and total and mild surgical complications at 12 months. **Conclusions:** This meta analysis supports the use of VP in treating distal radius fractures.

Keywords: *Locking plate, external fixation, distal radius fracture, metaanalysis*

MeSH terms: *Radius, fractures, bone plates, randomized controlled trials topic*

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Introduction

There is no consensus on the optimal treatment of distal radius fractures.[1] Methods range from nonoperative treatment to external and internal fixation. Fractures were deemed stable if there was an adequate initial reduction, defined as residual dorsal angulation of <10° (from neutral), loss of height of <2 mm compared with the contralateral side, articular step-off of ≤1 mm, and no associated instability of the distal radio-ulnar joint. These fractures can be treated nonoperatively with a satisfactory outcome.[2,3] For unstable types, if fractures can be reducible to an acceptable position by sustained countertraction using the concept of ligamentotaxis,[4] external fixation (EF) (with/without percutaneous Kirschner-wire)[5-8] is an effective way to treat this kind of trauma with minimal invasion. However, for some displaced or comminuted distal radius fractures, it is very difficult to obtain and maintain an ideal reduction, even with the use of EF. There is a consensus in the literature that these fractures require operative fixation such as intramedullary fixation[9] and internal fixation with various forms of implants.[10,11] In recent decades, internal fixation with volar locking plates (VPs) has become increasingly popular.[12] Theoretically, it can provide robust and satisfactory stability and reduce the damage of the dorsal extensor tendons due to the volar approach.[13] Although different types of fixation and many case series with good results have been published,[14-16] it remains controversial how best to treat distal radius fractures. Usually, the decision-making and the management are mainly based on the patient characteristics, fracture pattern, and orthopedist's clinical experience.

A number of systematic reviews and metaanalyses conducted to compare external and internal fixation of distal radial fractures have been performed before.[17-20] However, some of these studies included retrospective studies and case series, which might result in certain biases. More importantly, for internal fixation, there were a variety of plates including volar, dorsal, and volar combining dorsal plate. The heterogeneity of interventions may also lead to an unreliable conclusion. Walenkamp *et al*.[21,22] and Li-hai *et al*.[22] undertook two

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metaanalysis to compare VP with EF in treating distal radial fractures. In their studies, three and six randomized controlled trials (RCTs) were included, respectively, and the relatively small sample sizes of the included studies led to the limitation. Subsequently, several relevant RCTs were conducted,[23-25] but the reported results were inconsistent.

Therefore, a more precise updated metaanalysis should be carried out, which will make the result more persuasive. In this large scale metaanalysis of RCTs, we aim to compare the functional outcomes, radiological parameters, and complication rate between VP and EF with/without percutaneous in the treatment of distal radius fractures to improve our understanding and guide our management of this condition.

Materials and Methods

Search strategy

The systematic review was performed following the Preferred Reporting Items for Systematic Reviews and MetaAnalyses (PRISMA) statement.[26,27] The English language literature search was performed on PubMed and the Cochrane Central Register of Controlled Trials (1980 to December 2015) using the following Medical Subject Heading items in different combinations: distal radius fracture, VP, EF, treatment outcome, comparative study, and randomized trial. To identify other relevant studies, we also reviewed the references from the identified trials and review articles. Only those with full text available were considered.

Study selection

We have included articles based on the following inclusion criteria: (1) RCTs assessing VP versus EF (with or without supplementary percutaneous pinning) in treating closed distal radius fractures; (2) studies reported at least 1 of the following outcomes of interest: patient-rated functional outcome instrument scores disabilities of the arm, shoulder and hand (DASH); grip strength; wrist flexion and extension, forearm supination and pronation, ulnar deviation and radial deviation; radiograph-based parameters and rates of complications. The primary outcome measure of this metaanalysis was the DASH score at 3, 6, and 12 months followup. This is a validated self-reported, 30-item questionnaire designed to measure the upper extremity function and symptoms in fracture patients, with the total scale score ranging from 0 (no disability) to 100 (maximum disability).[28] The secondary outcome measures were: (1) grip strength and the range of motion (ROM) of injured wrist reported as a percentage of the uninjured side at 3, 6, and 12 months followup; (2) radiographic parameters at 12 months followup; and (3) complication rate. According to their different extent of severity, complications were divided into (i) mild complications, defined as temporary and self-healing, such as transient carpal tunnel syndrome (CTS) and tendonitis not requiring surgery, skin erythema, transient radial neurapraxia, excessive postoperative pain, and superficial infections not requiring antibiotics, (ii) moderate complications, defined as those with a need for further surgery or intravenous antibiotic treatment, but not affecting the final outcome, such as CTS and tendonitis requiring surgery, or deep infection requiring antibiotics, (iii) severe complications, defined as those influencing the final outcome and in need of surgical or other intervention, such as loss of reduction, malunion and nonunion requiring additional surgery or splinting, reflex sympathetic dystrophy, and tendon rupture.[29] RCTs regarding open fractures, retrospective studies, biomechanical studies, literature reviews and the studies that did not provide sufficient data, such as the patients' demographic characteristic or the information on surgery, diagnosis, followup, clinical outcomes and complications, were all excluded. Trials that compared different internal fixation techniques or other implants were also excluded.

Data extraction and quality assessment

All eligible studies were reviewed, and the reported means and standard deviations were extracted independently by 2 reviewers using a data collection form. Extracted data included patient characteristics (sample size, mean age, the proportion of females), fracture types (AO classification), protocol for the treatment of fractures, followup length, outcome measures, and complications. If standard deviations were not reported and could not be calculated from available data, we asked authors to supply the data. Quality assessment was judged on concealment of treatment allocation; similarity of both groups at baseline regarding prognostic factors; eligibility criteria; blinding of outcome assessors, care providers, and patients; completeness of followup; and intention-to-treat analysis. We quantified study quality using the Modified Jadad score [Table 1].[30] A third reviewer adjudicated any disagreement about extracted data and checked the extracted data for accuracy. The data were entered into the Review Manager (Version 5.2. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) database for further analysis.

Data analysis

Continuous variables (DASH scores, grip strength, ROM, and radiographic parameters) were analyzed using the weighted mean differences with its 95% confidence interval (CI), whereas dichotomous data (complication rate) was analyzed using the risk ratio (RR) measure with its 95% CI. Moreover, statistical heterogeneity across trials was quantified with I^2 statistic conforming to PRISMA guidelines.[26] I^2 value <25% was considered homogeneous, I^2 values of 25%, 50%, and 75% or more represent low, moderate, and high heterogeneity, respectively.[31] If the studies were homogeneous or the statistical heterogeneity was low, a fixed-effect model was used to assess the overall estimate. Otherwise, a random-effect model was chosen.[32] Sensitivity analyses (exclusion of one study at a time) were

Table 1: Modified Jadad score

Items	Score standard			Score
	0	1	2	
Randomization	Not randomized or inappropriate method of randomization	The study was described as randomized	The method of randomization was described and it was appropriate	
Concealment of allocation	Not describe the method of allocation concealment	The study was described as using allocation concealment method	The method of allocation concealment was described appropriately	
Double blinding	No blind or inappropriate method of blinding	The study was described as double-blind	The method of double blinding was described and it was appropriate	
Withdrawals and dropouts	Not describe the followup	A description of withdrawals and dropouts		
Total				

conducted to assess heterogeneity and robustness of pooled results. We assessed for potential publication bias using a funnel plot. All tests were two-tailed and a $P < 0.05$ was considered as statistically significant in this meta-analysis.

Results

Literature search

All potentially relevant articles and abstracts were reviewed, of which 9 published RCTs[23-25,33-38] with a total of 776 patients fulfilled all inclusion criteria for our meta-analysis. The included study characteristics are summarized in Table 2, exhibiting the information of authors, year of publication, patient age range, sample size, fracture types, intervention forms, length of the followup period, and Jadad scores.

Meta-analysis of disabilities of the arm, shoulder and hand scores

Four studies with 304 patients (VP, $n = 150$; EF, $n = 154$) independently reported the patients' self-reported outcome-DASH scores. The analysis revealed a significant difference in pooled treatment effect favoring VP at 3 months followup (mean difference = −12.96; 95% CI: −21.11 to −4.82; $P = 0.002$; $I^2 = 77\%$). Similar significant results were obtained at 6 months (mean difference = −6.20; 95% CI: −9.83 to −2.58; $P = 0.0008$; $I^2 = 0\%$), as well as at 12 months postoperatively (mean difference = −6.39; 95% CI: −11.91 to −0.87; $P = 0.02$; $I^2 = 62\%$) [Figure 1].

Metaanalysis of grip strength

Grip strength values (measured as a percentage of the contralateral uninjured wrist) were pooled across eight studies with 665 patients (VP, $n = 322$; EF, $n = 343$). At 3 months, we found significant superior grip strength in patients receiving the treatment of VP compared with those receiving EF (mean difference = 14.19; 95% CI: 7.65–20.73; $P < 0.0001$; $I^2 = 63\%$). However, analysis for grip strength revealed no significant difference (mean difference = 3.46; 95% CI: −3.76–10.68; $P = 0.35$; $I^2 = 81\%$ and mean difference = 3.38; 95% CI: −1.14–7.90; $P = 0.14$; $I^2 = 49\%$, respectively) at 6 and 12 months of followup between this two treatment arms, so no method was favored [Figure 2].

Metaanalysis of range of motion

ROM data (expressed as a percentage of the contralateral uninjured wrist) including flexion, extension, pronation, supination, radial deviation, and ulnar deviation that were pooled across six studies are summarized in Table 3. Analysis of these data revealed that compared with EF group, the pooled treatment effect regarding flexion, extension and supination ability was statistically superior (mean difference = 5.99; 95% CI: 0.62–11.35; $P = 0.03$, $I^2 = 57\%$, mean difference = 10.90; 95% CI: 1.50–20.30; $P = 0.02$; $I^2 = 79\%$ and mean difference = 4.82; 95% CI: 0.53–9.11; $P = 0.03$; $I^2 = 34\%$, respectively) at 3 months followup among patients in VP group. And a statistically significant difference in ulnar deviation was found at 6 months postoperatively in favor of EF (mean difference = −5.59; 95% CI: −8.84 to −2.35; $P = 0.0007$; $I^2 = 0\%$). No other ROM parameters revealed any significant differences in treatment effect between the two groups at any interval time after fixation.

Metaanalysis of radiographic parameters

Five studies with 350 patients (VP, $n = 172$; EF, $n = 178$) reported the volar tilt, three with 185 patients (VP, $n = 87$; EF, $n = 98$) reported the radial inclination and two with 111 patients (VP, $n = 51$; EF, $n = 60$) reported the radial length at 12 months followup. Metaanalysis of these three parameters showed no significant difference between the two methods compared. However, parameters regarding ulnar variance pooled across three studies with 185 patients (VP, $n = 87$; EF, $n = 98$) revealed significant differences with smaller ulnar variance in VP group (Mean difference = −0.82; 95% CI: −1.39 to −0.25; $P = 0.005$; $I^2 = 0\%$) at 12 months after fixation [Table 4].

Metaanalysis of complications

All the 9 eligible studies with 776 patients provided information on surgical complications. In total, a complication rate of 21.39% in the VP group and 27.86%

Table 2: Characteristics of included studies

Authors, year	Study design	Number of fracture (VP/EF)	Female proportion, % (VP/EF)	Mean age±SD (range), year (VP/EF)	AO classification of fracture	Intervention type		Followup time	Jadad score
						VP	EF		
Egol *et al*., 2008	RCT	44/44	39/38	52.2 (19-87)/49.9 (18-78)	A B C	Locked volar plate	Bridging EF (±K-wire)	2 and 6 weeks and 3, 6 and 12 months	6
Wei *et al*., 2009	RCT	12/22	75/72	61±18/55±16	A3 C1-3	Locked volar plate	Bridging external fixator + K-wires	6 weeks and 3, 6 and 12 months	6
Wilcke *et al*., 2011	RCT	33/30	76/77	55 (20-69)/56 (21-69)	A C1	Volar locked plate	Bridging external fixator (±K-wires)	10 days, 5 weeks, and 3, 6 and 12 months	5
Jeudy *et al*., 2012	RCT	36/39	72/79	64.7±3.7/64.6±3.5	C2 C3	Volar locked plate	External fixator (±pins)	3, 6, 12 and 24 weeks	4
Gradl *et al*., 2013	RCT	52/50	87	63 (18-88)	A3 C1-3	Volar fixed angle plate	Nonbridging external fixator (±K-wires)	8 weeks, 6 months and 1 year	4
Karantana *et al*., 2013	RCT	66/64	61/78	48±15/51±16	A3 C2 C3	VP	K-wires±bridging external fixator	6, 12 weeks and 1 year	4
Williksen *et al*., 2013	RCT	52/59	80	54 (20-84)	A2-3 C1-3	Volar locked plate	External fixator and K-wires	6, 16, 26 and 52 weeks	2
Roh *et al*., 2014	RCT	36/38	30/36	54.4±10.9/55.3±11.2	C2 C3	VP	Bridging external fixator + K-wires	3, 6 and 12 months	5
Shukla *et al*., 2014	RCT	48/62	58/53	39.33±13.1/38.95±13.1	C	Volar locked plate	Bridging external fixator	6 months and 1 year	3

RCT=Randomized controlled trial, VP=Volar locking plate, EF=External fixation, SD=Standard deviation, AO=Arbeitsgemeinschaft für Osteosynthesefragen

Table 3: Range of motion at 3, 6, and 12 months followup

Followup time	Clinical outcome (%)	Studies	Fractures		MD	95% CI	*P*	Favored
			VP	EF				
3 months	Flexion	5	186	192	5.99	0.62-11.35	0.03	VP
	Extension	4	150	154	10.90	1.50-20.30	0.02	VP
	Pronation	4	153	162	3.42	−2.99-9.83	0.30	-
	Supination	3	117	124	4.82	0.53-9.11	0.03	VP
	Ulnar deviation	2	51	60	−0.11	−3.67-3.54	0.95	-
	Radial deviation	2	51	60	8.70	−34.40-51.80	0.69	-
6 months	Flexion	5	172	178	4.26	−2.49-11.01	0.22	-
	Extension	4	136	140	9.73	−6.40-25.85	0.24	-
	Pronation	3	87	98	12.44	−4.40-29.29	0.15	-
	Supination	3	103	110	1.90	−2.64-6.44	0.41	-
	Ulnar deviation	3	103	110	−5.59	−8.84-−2.35	0.0007	EF
	Radial deviation	3	103	110	−5.97	−21.49-9.55	0.45	-
12 months	Flexion	6	238	242	−0.12	−2.56-2.32	0.92	-
	Extension	5	202	204	0.95	−3.53-5.43	0.68	-
	Pronation	4	153	162	0.71	−2.94-4.37	0.70	-
	Supination	4	169	174	−0.54	−1.96-0.87	0.45	-
	Ulnar deviation	3	103	110	−0.68	−3.85-2.49	0.68	-
	Radial deviation	3	103	110	−3.53	−7.26-0.20	0.06	-

VP=Volar locking plate, EF=External fixation, MD=Mean difference, CI=Confidence interval

in the EF group was found from the pooled result. The metaanalysis for overall complication rate revealed that, compared to EF, there was a statistically significant difference favoring VP (RR = 0.75; 95% CI: 0.58–0.95;

Study or Subgroup	VP Mean	VP SD	VP Total	EF Mean	EF SD	EF Total	Weight	Mean Difference IV, Random, 95% CI	Year
2.1.1 DASH scores at 3 months									
Egol 2008	19.5	20.1	39	25.4	21.1	38	23.0%	-5.90 [-15.11, 3.31]	2008
Wei 2009	7	5	12	29	18	22	24.7%	-22.00 [-30.04, -13.96]	2009
Wilcke 2011	9	8.79	33	27	19.56	30	25.3%	-18.00 [-25.61, -10.39]	2011
Karantana 2013	21	17	66	27	20	64	27.1%	-6.00 [-12.39, 0.39]	2013
Subtotal (95% CI)			**150**			**154**	**100.0%**	**-12.96 [-21.11, -4.82]**	
Heterogeneity: Tau² = 53.17; Chi² = 13.32, df = 3 (P = 0.004); I² = 77%									
Test for overall effect: Z = 3.12 (P = 0.002)									
2.1.2 DASH scores at 6 months									
Egol 2008	25	21.7	39	32.6	23.8	38	12.7%	-7.60 [-17.78, 2.58]	2008
Wei 2009	6	4	12	11	10	22	58.2%	-5.00 [-9.75, -0.25]	2009
Wilcke 2011	6	8.79	33	14	16.77	30	29.2%	-8.00 [-14.71, -1.29]	2011
Subtotal (95% CI)			**84**			**90**	**100.0%**	**-6.20 [-9.83, -2.58]**	
Heterogeneity: Tau² = 0.00; Chi² = 0.59, df = 2 (P = 0.74); I² = 0%									
Test for overall effect: Z = 3.36 (P = 0.0008)									
2.1.3 DASH scores at 12 months									
Egol 2008	13	30.9	39	17.2	33.7	38	10.9%	-4.20 [-18.65, 10.25]	2008
Wei 2009	4	5	12	18	14	22	27.0%	-14.00 [-20.50, -7.50]	2009
Wilcke 2011	7	8.79	33	11	13.96	30	29.1%	-4.00 [-9.83, 1.83]	2011
Karantana 2013	9	12	66	12	15	64	32.9%	-3.00 [-7.68, 1.68]	2013
Subtotal (95% CI)			**150**			**154**	**100.0%**	**-6.39 [-11.91, -0.87]**	
Heterogeneity: Tau² = 18.38; Chi² = 7.91, df = 3 (P = 0.05); I² = 62%									
Test for overall effect: Z = 2.27 (P = 0.02)									
Test for subgroup differences: Chi² = 2.29, df = 2 (P = 0.32), I² = 12.5%									

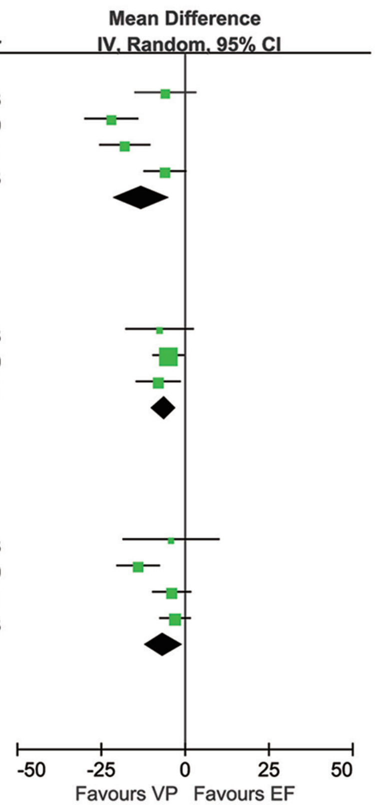


Figure 1: Table and forest plot illustrating mean difference in disabilities of the arm, shoulder and hand scores at 3, 6, and 12 months followup between volar locking plate and external fixation

Table 4: Radiological outcomes at 12 months followup

Radiological outcome	Studies	MD (95% CI)	*P*	Favored
Volar tilt (degree from neutral)	5	1.46 (−4.13-7.04)	0.61	-
Radial inclination (°)	3	−0.95 (−3.60-1.69)	0.48	-
Radial length (mm)	2	−0.96 (−1.96-0.04)	0.06	-
Ulnar variance (mm)	3	−0.82 (−1.39-−0.25)	0.005	VP

CI=Confidence interval, MD=Mean difference, VP=Volar locking plate

P = 0.02; I^2 = 0%) during the followup period [Figure 3]. Further analyses [Figure 4] also indicated that mild complications in VP group were statistically less than in EF group (RR = 0.55; 95%CI: 0.39–0.79; P = 0.001; I^2 = 0%), whereas no significant difference in moderate and severe complications was detected (RR = 1.12; 95% CI: 0.69–1.82; P = 0.65; I^2 = 18% and RR = 1.12; 95% CI: 0.60–2.08; P = 0.72; I^2 = 27%, respectively).

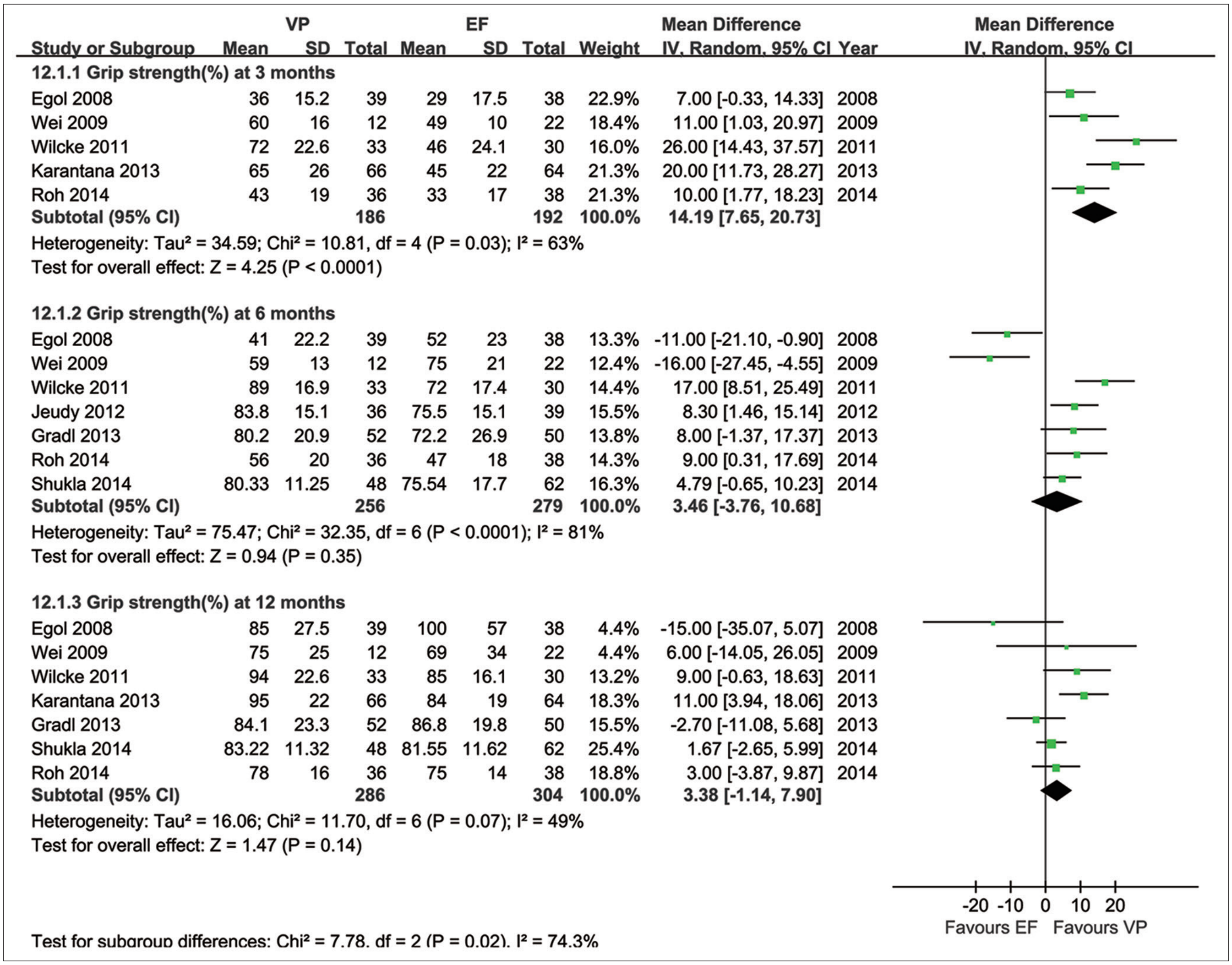
Sensitivity analysis and publication bias analysis

For the purpose of investigating the potential publication bias, funnel plots based on the results of complication data was graphed and the funnel plot did not reveal obvious asymmetry. The robustness of results was assessed by the performing of sensitivity analyses, which demonstrated that no individual study affected the overall RR predominantly.

Discussion

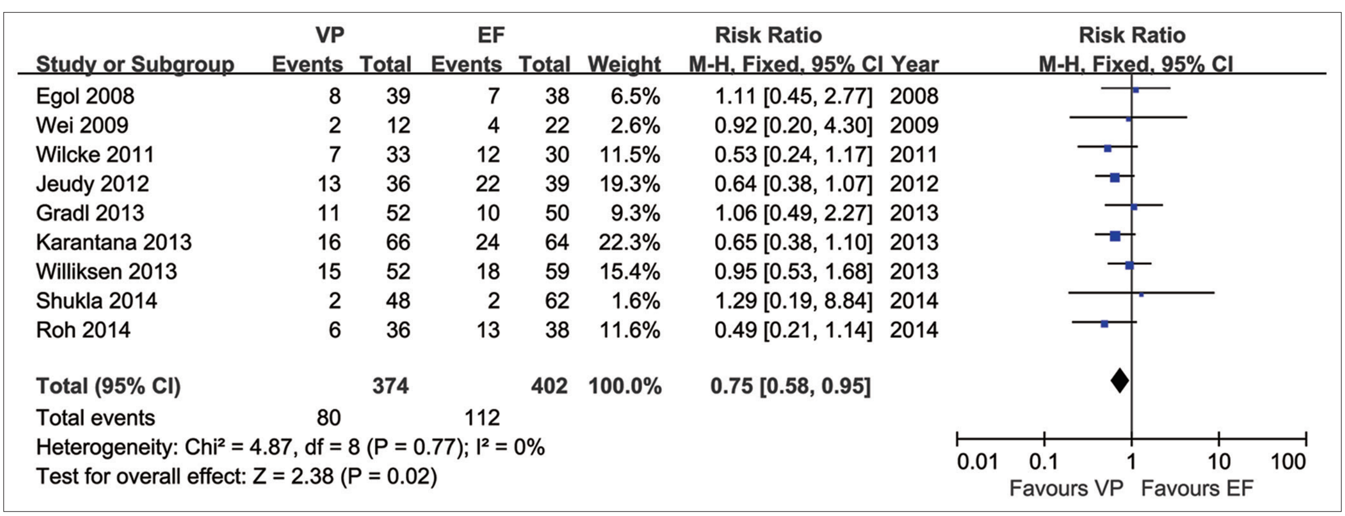
This metaanalysis represents 9 RCTs of VP versus EF, which is the largest sample size to date analyzing the treatment effect of these two procedures. According to the best estimates from our metaanalysis, management with VP leads to lower DASH scores compared to EF throughout the 12 month followup period. These results are similar to the findings of Wang *et al*.[19] but different from the 12 month outcomes of Xie *et al*.[20]

To fully appreciate the findings, we analyzed the clinical relevance of the differences of DASH scores to make the statistical differences more meaningful and practical. The minimal clinically important difference in DASH scores for the wrist pathology ranges from 10 to 15 points.[21,28] Results of the analysis showed that the difference was 12.96 at 3 months, which was within that range. Hence, this difference in favor of VP at 3 months should be considered not only statistically significant but also clinically relevant for the patients. For VP, direct visualization and manipulation of the bone fragments could provide better anatomic restoration and stable rigid fixation, which could make it possible for immediate wrist postoperative active motion and excellent prognosis in initial stage. Interestingly, the differences at 6 and 12 months while still statistically significant, no longer meet the clinically relevant difference noted above.



Study or Subgroup	VP Mean	VP SD	VP Total	EF Mean	EF SD	EF Total	Weight	Mean Difference IV, Random, 95% CI	Year
12.1.1 Grip strength(%) at 3 months									
Egol 2008	36	15.2	39	29	17.5	38	22.9%	7.00 [-0.33, 14.33]	2008
Wei 2009	60	16	12	49	10	22	18.4%	11.00 [1.03, 20.97]	2009
Wilcke 2011	72	22.6	33	46	24.1	30	16.0%	26.00 [14.43, 37.57]	2011
Karantana 2013	65	26	66	45	22	64	21.3%	20.00 [11.73, 28.27]	2013
Roh 2014	43	19	36	33	17	38	21.3%	10.00 [1.77, 18.23]	2014
Subtotal (95% CI)			**186**			**192**	**100.0%**	**14.19 [7.65, 20.73]**	
Heterogeneity: Tau² = 34.59; Chi² = 10.81, df = 4 (P = 0.03); I² = 63%									
Test for overall effect: Z = 4.25 (P < 0.0001)									
12.1.2 Grip strength(%) at 6 months									
Egol 2008	41	22.2	39	52	23	38	13.3%	-11.00 [-21.10, -0.90]	2008
Wei 2009	59	13	12	75	21	22	12.4%	-16.00 [-27.45, -4.55]	2009
Wilcke 2011	89	16.9	33	72	17.4	30	14.4%	17.00 [8.51, 25.49]	2011
Jeudy 2012	83.8	15.1	36	75.5	15.1	39	15.5%	8.30 [1.46, 15.14]	2012
Gradl 2013	80.2	20.9	52	72.2	26.9	50	13.8%	8.00 [-1.37, 17.37]	2013
Roh 2014	56	20	36	47	18	38	14.3%	9.00 [0.31, 17.69]	2014
Shukla 2014	80.33	11.25	48	75.54	17.7	62	16.3%	4.79 [-0.65, 10.23]	2014
Subtotal (95% CI)			**256**			**279**	**100.0%**	**3.46 [-3.76, 10.68]**	
Heterogeneity: Tau² = 75.47; Chi² = 32.35, df = 6 (P < 0.0001); I² = 81%									
Test for overall effect: Z = 0.94 (P = 0.35)									
12.1.3 Grip strength(%) at 12 months									
Egol 2008	85	27.5	39	100	57	38	4.4%	-15.00 [-35.07, 5.07]	2008
Wei 2009	75	25	12	69	34	22	4.4%	6.00 [-14.05, 26.05]	2009
Wilcke 2011	94	22.6	33	85	16.1	30	13.2%	9.00 [-0.63, 18.63]	2011
Karantana 2013	95	22	66	84	19	64	18.3%	11.00 [3.94, 18.06]	2013
Gradl 2013	84.1	23.3	52	86.8	19.8	50	15.5%	-2.70 [-11.08, 5.68]	2013
Shukla 2014	83.22	11.32	48	81.55	11.62	62	25.4%	1.67 [-2.65, 5.99]	2014
Roh 2014	78	16	36	75	14	38	18.8%	3.00 [-3.87, 9.87]	2014
Subtotal (95% CI)			**286**			**304**	**100.0%**	**3.38 [-1.14, 7.90]**	
Heterogeneity: Tau² = 16.06; Chi² = 11.70, df = 6 (P = 0.07); I² = 49%									
Test for overall effect: Z = 1.47 (P = 0.14)									
Test for subgroup differences: Chi² = 7.78, df = 2 (P = 0.02), I² = 74.3%									

Figure 2: Table and forest plot illustrating mean difference in Grip strength (measured as a percentage of the uninjured wrist) at 3, 6, and 12 months followup between volar locking plate and external fixation



Study or Subgroup	VP Events	VP Total	EF Events	EF Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Egol 2008	8	39	7	38	6.5%	1.11 [0.45, 2.77]	2008
Wei 2009	2	12	4	22	2.6%	0.92 [0.20, 4.30]	2009
Wilcke 2011	7	33	12	30	11.5%	0.53 [0.24, 1.17]	2011
Jeudy 2012	13	36	22	39	19.3%	0.64 [0.38, 1.07]	2012
Gradl 2013	11	52	10	50	9.3%	1.06 [0.49, 2.27]	2013
Karantana 2013	16	66	24	64	22.3%	0.65 [0.38, 1.10]	2013
Williksen 2013	15	52	18	59	15.4%	0.95 [0.53, 1.68]	2013
Shukla 2014	2	48	2	62	1.6%	1.29 [0.19, 8.84]	2014
Roh 2014	6	36	13	38	11.6%	0.49 [0.21, 1.14]	2014
Total (95% CI)		**374**		**402**	**100.0%**	**0.75 [0.58, 0.95]**	
Total events	80		112				
Heterogeneity: Chi² = 4.87, df = 8 (P = 0.77); I² = 0%							
Test for overall effect: Z = 2.38 (P = 0.02)							

Figure 3: Table and forest plot illustrating risk ratio in total surgical complications at 12 months followup between volar locking plate and external fixation

As compared to the EF group, pooled data from the eligible studies revealed that distal radial fractures with the treatment of VP led to superior performance in terms of the recovery of grip strength, flexion, extension, and supination

Study or Subgroup	VP Events	VP Total	EF Events	EF Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Egol 2008	8	39	7	38	10.6%	1.11 [0.45, 2.77]	2008
Wei 2009	2	12	3	22	3.2%	1.22 [0.24, 6.33]	2009
Wilcke 2011	3	33	6	30	9.4%	0.45 [0.12, 1.66]	2011
Jeudy 2012	11	36	21	39	30.1%	0.57 [0.32, 1.01]	2012
Karantana 2013	5	66	11	64	16.7%	0.44 [0.16, 1.20]	2013
Gradl 2013	1	52	5	50	7.6%	0.19 [0.02, 1.59]	2013
Williksen 2013	2	52	8	59	11.2%	0.28 [0.06, 1.28]	2013
Shukla 2014	1	48	2	62	2.6%	0.65 [0.06, 6.91]	2014
Roh 2014	3	36	6	38	8.7%	0.53 [0.14, 1.95]	2014
Total (95% CI)		**374**		**402**	**100.0%**	**0.55 [0.39, 0.79]**	
Total events	36		69				

Heterogeneity: Chi² = 5.20, df = 8 (P = 0.74); I² = 0%

Test for overall effect: Z = 3.23 (P = 0.001)

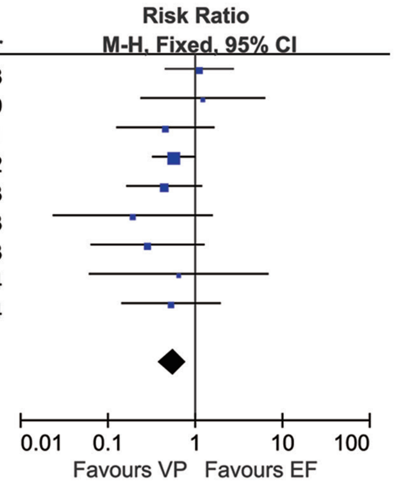


Figure 4: Table and forest plot illustrating risk ratio in mild surgical complications at 12 months followup between volar locking plate and external fixation

at 3 months. No significant difference was found at 6 or 12 months followup period. Delayed wrist functional exercise in EF group may explain the disadvantage over VP group in early time. Patients in EF group began to take functional exercises after the removal of external fixator at approximately 6–8 weeks after the operation. Only from then on the grip strength began to recover and the initial weakness and stiffness gradually improved. As a result, the differences were not significant at 6 and 12 months. Besides, the analysis reveals that EF led to significantly better ulnar deviation at 6 months followup. The difference was, however, small and the overall ulnar deviation results equalized at 12 months. Therefore, the clinical relevance of this difference at 6 months remains uncertain.

Radiographic assessment of volar tilt, radial inclination, radial length, and ulnar variance was compared to published norms[18,39,40] to assess the accuracy and the stability of the reduction. Late collapse of fixation, which is an important inducing factor of malunion, will occur in a considerable number of cases even though there was good initial anatomic reduction, especially in EF. Kawaguchi *et al*.[41] have reported in their study that secondary displacements occurred in more than 50% of the cases when EF was used. Our analysis revealed that VP demonstrated significantly less ulnar positive variance than EF at 12 months. However, this difference in ulnar positive variance did not translate to a statistical advantage in radial length or radial inclination. No significant loss of reduction with either treatment after the last followup means EF actually will not increase the risk of late collapse compared with VP. In Walenkamp *et al*.'s study,[21] a significant difference in volar tilt was observed in favor of treatment with a VP. However, that was not detected in our metaanalysis. The explanation for this result could be that when we analyzed these parameters, there was a lack of eligible study and the sample size was relatively small. Hence, the estimation may be less precise, and the data should be interpreted with caution.

In our metaanalysis, there were 3 studies[24,25,38] focused only on displaced intraarticular (AO type C) fractures. The intraarticular distal radius fracture is a very common type which occupies 10% to 12% of whole fractures and 77% of this complicated fracture accompanies the sigmoid notch involvement.[42,43] Shukla[24] showed that EF had superiority over VP at outcome at 1-year followup. However, patients in his study were relatively young. On the contrary, Jeudy *et al*.[38] and Roh *et al*.[25] both found VP had superior radiological outcome and better functional recovery without provoking further complications. We prefer to support the latter because we believe that direct manipulation and fixation of bone fragments may be better for restoring articular congruence of the distal end of the radius.

Our metaanalysis found that VP led to fewer total and mild surgical complications at 12 months followup. In the metaanalysis of Walenkamp *et al*. in 2013 and Xie *et al*. in 2013, they reported similar outcomes that there seemed to be a slight trend for patients treated with VP to suffer fewer complications than those treated with EF. However, no significant difference was found between the two groups at final followup, which was different from our results. Considering that all the 9 RCTs with large sample size included in our metaanalysis recorded the complication rate, funnel plot, and sensitivity analysis indicating the study was robust and reliable, we have reasons to believe our results are more precise and the complication rate is indeed lower with VP than EF at 12 months.

Several limitations exist in this metaanalysis, the results of our study should be interpreted with caution. The first is the potential study heterogeneity regarding mean patient age, the proportion of women and different fracture types. We could not completely match the cohorts to conduct the subgroup analysis. Besides, we did not study treatment cost, which is a subject of current debate. In addition, the varied surgeons with different levels of surgical experience among the included studies could also influence the results.

It is worth pointing out distal radius fracture with the involvement of the volar ulnar fragment, also known as the "critical corner," is a special kind of fracture.[44] Failure to reduce this fragment can lead to instability at joint surface and malunion may occur. Due to its unique anatomy, EF alone cannot provide rigid fixation. To maintain reduction, some of the included RCTs used EF with temporary subchondral K-wires to secure volar ulnar fragment. However, they did not carry out separate analysis of the outcome of this type of fracture. To avoid these limitations, more RCTs with higher methodological qualities are needed to obtain more convincing evidence.

In summary, the findings of this metaanalysis favor VP for improved early clinical outcomes including DASH scores, grip strength, flexion, extension, and supination, suggesting that it is likely to facilitate a more rapid functional recovery which may be advantageous for specific patients who desire an accelerated return of function. In the long run, IF is also advantageous over EF regarding the DASH scores, maintenance of ulnar variance and the total and mild surgical complications. Hence, we support the use of VP in the management of distal radius fractures.

Conclusions

In summary, the findings of this metaanalysis favor VP in early postoperative period in terms of DASH scores, grip strength, flexion, extension and supination, suggesting that it is likely to facilitate a more rapid functional recovery which may be advantageous for specific patients who desire an accelerated return of function, like the young or the athletes. In the long run, IF is also advantageous over EF regarding the DASH scores, maintenance of ulnar variance and the total and mild surgical complications. Hence, we fairly support the use of VP in the management of distal radius fractures.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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