Int J Clin Exp Med 2019;12(3):2097-2106
www.ijcem.com /ISSN:1940-5901/IJCEM0078049

Review Article

The efficacy of volar locking plates and external fixation for patients with unstable distal radial fractures: a meta-analysis

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Received September 22, 2017; Accepted September 12, 2018; Epub March 15, 2019; Published March 30, 2019

Abstract: Questions/Purposes: In this meta-analysis, we compared the use of volar locking plates (VLPs) with external fixation (EF) for unstable distal radial fractures. Materials and methods: A systematic review of the literature was conducted to identify randomized controlled trials (RCTs) using VLPs and EF in patients with unstable distal radial fractures. Trials were performed before July 2017 and retrieved using MEDLINE, Embase, and the Cochrane Library databases. The meta-analysis was performed using STATA version 12.0. Results: Ten RCTs with a total of 932 patients were included. Of these, 451 were in the VLP group and 481 in the EF group. The VLP group had a higher Disabilities of the Arm, Shoulder and Hand score at 3 months ($P<0.001$) and 6 months ($P<0.001$); the scores were comparable for the groups at 12 months ($P=0.166$). Range of motion was better in the VLP group at 3 months. No difference between the groups was seen at 6 and 12 months. Grip strength in the VLP group was significantly greater than that in the EF group at 3 months ($P<0.001$); no difference between the groups was seen at 6 ($P=0.526$) and 12 months ($P=0.507$). There was no significant difference in reoperation and complication rates between the two procedures. Conclusions: We found that VLP may have improved functional recovery in the early period after surgery, but patients undergoing either VLP or EF showed similar levels of functional recovery at a later stage. The study was limited by the heterogeneity of the trials and should be interpreted with caution. Multicenter RCTs of higher quality and with larger sample numbers are needed.

Keywords: Distal radial fractures, external fixation, volar plate, meta-analysis

Introduction

Imaging findings in patients with unstable distal radial fractures include angular displacement >10°, radial shortening >5 mm, and articular surface step-off >2 mm. Lateral radiographs over the midline may show a comminuted fracture in a volar view and a dorsal cortical comminuted fracture. Good reduction is difficult to achieve in these fractures.

Restoration of the articular surface, stable fixation, and early wrist motion are crucial factors in the treatment of patients with unstable distal radial fractures [1]. Several techniques can be used to manage unstable fractures of the distal radius, such as closed reduction with percutaneous Kirschner wires [2], pins and plaster, closed reduction with external fixation (EF) [3], and internal fixation (IF) with plates [4]. IF is the most common method used, especially with volar locking plates (VLPs) [5]. EF is another option. However, extensive dissection of soft tissue around the fracture zone compromises the biological environment for fracture healing and increases the risk of nonunion or malunion. The incidence of complications is reportedly 9.7-15%, with tendon problems and complex regional pain syndrome being most prevalent [6-9]. VLPs offer a biomechanical advantage when treating patients with an unstable distal radius [10]. Unlike open surgery, EF is a closed, minimally invasive method in which the fractured bone is not exposed to direct view [3]. EF is also a less demanding, less invasive, and faster procedure [11]. However, whether VLP

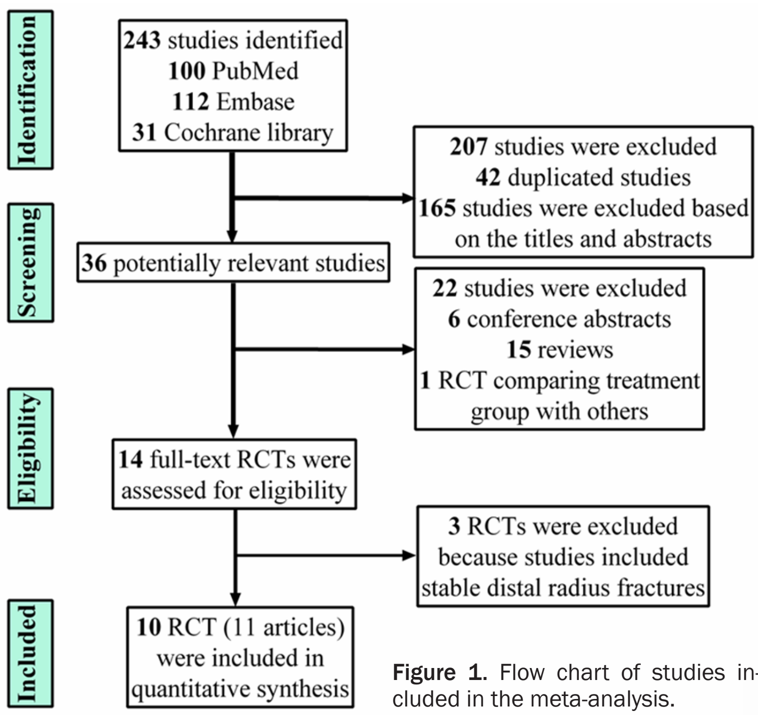

Figure 1. Flow chart of studies included in the meta-analysis.

use is better than EF use for unstable distal radial fractures is unclear.

Therefore, we performed a meta-analysis to compare the results of open reduction and IF with VLPs versus EF in patients with complex fractures of the wrist combining serious metaphyseal comminution and articular involvement. The outcomes of interest included clinical, functional, and radiological results, and complication rates.

Materials and methods

Literature search

We searched MEDLINE (1966 to July 2017), Embase (1974 to July 2017), and the Cochrane Library (through issue 6 of 12, 2017) databases using the keywords "radius", "fractures", "external fixation", "EF", and "plate". Retrieval dates included the time from database creation to July 2017.

Inclusion criteria

Inclusion criteria were as follows: randomized controlled trial (RCT); participants with unstable distal radial fractures; patients and controls who underwent EF or volar plating; primary endpoints of Disabilities of the Arm, Shoulder and Hand (DASH) score, range of motion, or grip strength; and secondary endpoints of Visual Analogue Scale (VAS) scores, complications, or radiological measurements.

Data extraction and quality evaluation

We screened all titles of retrieved articles and removed duplicates. After eliminating irrelevant articles, summaries of the remaining studies were assessed to confirm the adequacy of information. This was followed by full reading of the article. Two investigators resolved disagreements through discussion, and unresolved disagreements were discussed with a third investigator. We assessed the RCTs using the Cochrane Library Handbook 5.1 for major components as follows: adequate sequence generation, allocation concealment, blinding, incomplete outcome data, freedom from selective reporting, freedom from other bias, baseline balance between groups, no funding support, and valid sample size estimation.

Statistical methods

Relative risk (RR) and weighted mean difference (WMD) were used for effect size, with 95% confidence intervals (95% CIs). The Mantel-Haenszel (M-H) or inverse variance (I-V) was used as the statistical method. We assessed heterogeneity with I^2 statistics. During quantitative synthesis, a fixed-effects model was employed when heterogeneity was low (I^2<50%, P>0.1). When heterogeneity was high (I^2>50%, P<0.1), subgroup analysis was performed to explore possible sources of heterogeneity, or a random-effects model was used. We also used endpoint substantive knowledge as a factor in the selection model. P<0.05 was considered a statistically significant difference. STATA 12.0 version (STATA Corporation, College Station, TX, USA) was used to perform the analysis.

Results

Process for selecting trials

Most of the 243 potential eligible citations were excluded due to lack of relevance. After all

Table 1. Summary of included studies

Study	Country	Types of fraction	No. of patients		Age (years)		Women		Outcomes	Follow-up
			EF	VP	EF	VP	EF	VP		
Egol 2008 [1]	America	AO A/B/C	44	44	49.9	52.2	22	25	Radiological measurements, DASH scores, function, complications	12 months
Gradl 2013 [3]	America	AO A3/C1/C2/C3	50	52	63	63	-	-	Radiological measurements, function, complications	12 months
Jeudy 2012 [5]	France	AO C1/C2/C3	39	36	64.6	64.7	31	26	Radiological measurements, function, complications	6 months
Navarro 2016 [11]	Sweden	AO A2/A3/C1/C2/C3	70	70	63	63	65	63	Radiological measurements, function, complications	12 months
Roh 2015 [15]	Korea	AO C2/C3	38	36	55.3	54.4	16	14	Radiological measurements, function, complications	12 months
Shukla 2014 [19]	India	Cooney's type IV	62	48	38.95	39.33	33	28	Function, complications	12 months
Wei 2009 [22]	America	AO A3/C1/C2/C3	22	12	55	61	16	9	DASH scores, function, complications	12 months
Wilcke 2011 [23]	Sweden	AO A/C	30	33	56	55	23	25	DASH scores, function, complications	12 months
Williksen 2013 [24] Williksen 2015 [25]	Norway	AO A2/A3/C1/C2/C3	60	54	54	54	-	-	DASH scores, function, complications	60 months
Li 2015 [10]	China	AO A3/B3/C1/C2/C3	61	61	64.4	64.7	50	52	Radiological measurements, function, complications	12-28 months

Table 2. Quality of observational studies

Studies	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding to participants and personnel (performance bias)	Blinding to outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Egol 2008 [1]	Low risk	Low risk	High risk	Unclear	Low risk	Low risk	Unclear
Gradl 2013 [3]	Low risk	Unclear	High risk	Unclear	Low risk	Low risk	Unclear
Jeudy 2012 [5]	Low risk	Low risk	High risk	Unclear	Low risk	Low risk	Unclear
Navarro 2016 [11]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Unclear
Roh 2015 [15]	Low risk	Unclear	High risk	Unclear	Low risk	Low risk	Unclear
Shukla 2014 [19]	Low risk	Unclear	High risk	Unclear	Low risk	Low risk	Unclear
Wei 2009 [22]	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	Unclear
Wilcke 2011 [23]	Low risk	Low risk	High risk	Unclear	Low risk	Low risk	Unclear
Williksen 2013 [24] Williksen 2015 [25]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Unclear
Li 2015 [10]	Low risk	Unclear	High risk	Unclear	Low risk	Low risk	Unclear

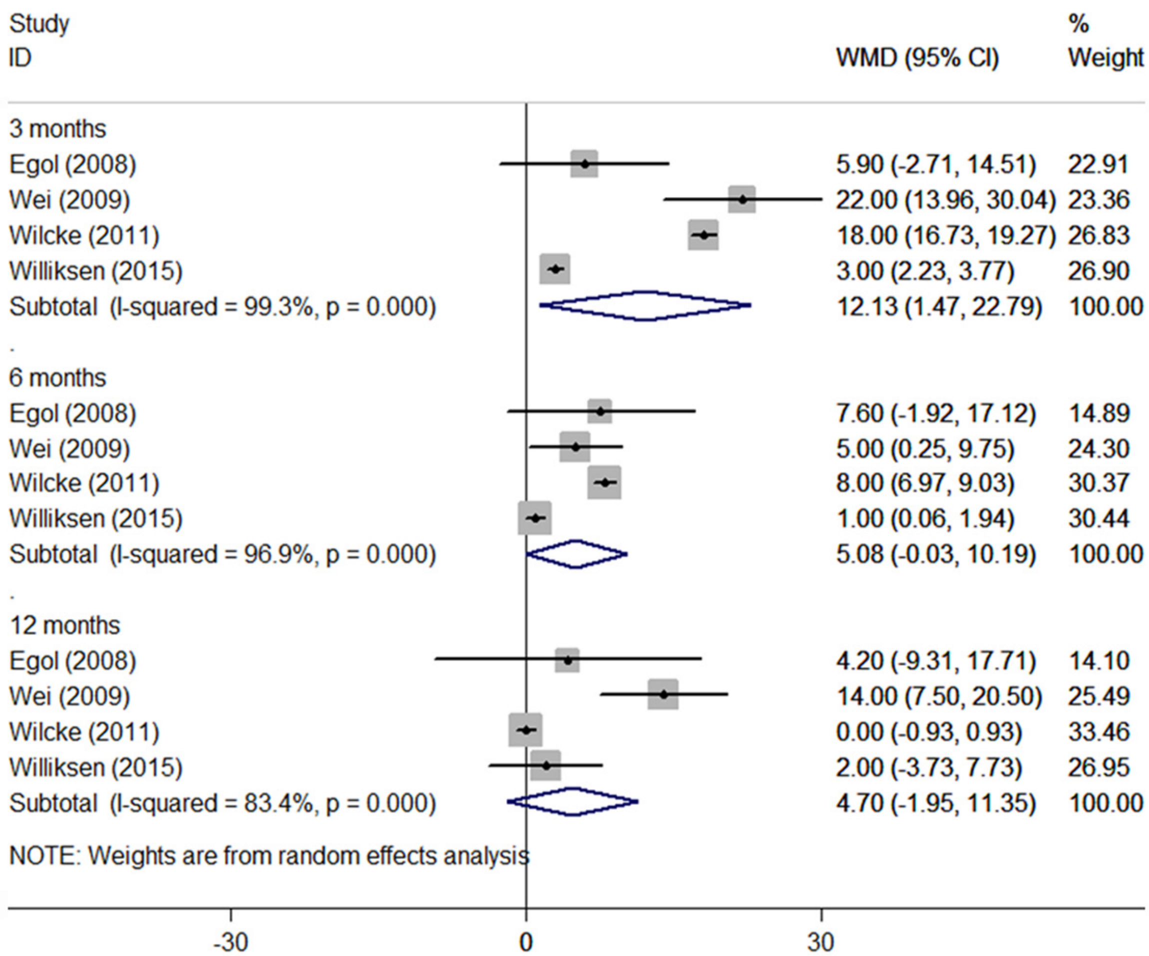

Figure 2. Forest plot comparing DASH scores in the EF and VLP groups.

exclusions were removed, 10 RCTs (11 articles) satisfied the inclusion criteria after screening and assessing potentially relevant studies. **Figure 1** shows the flow of studies through the trial.

Characteristics of included trials and quality evaluation

Except for a study by Shukla [12], all RCTs reported fractures using the AO/OTA classification. Ten RCTs with a total of 932 patients were included. Of these, 451 were in the VLP group and 481 in the EF group. All studies focused on function and complications, including 4 studies [13-17] that examined DASH scores and 6 [13, 18-22] that evaluated radiological measurements. One study [16, 17] had a follow-up period of 60 months, with 12-28 months reported in a study by Li, 6 months in a study by Jeudy, and 12 months in 7 other studies [12-14, 16-18, 21, 22] (**Table 1**).

The results of the quality evaluation are shown in **Table 2**. Random sequence generation, incomplete outcome data, and selective reporting showed a low risk of bias in all studies. Allocation concealment showed a low risk of bias in 6 studies [13, 19, 21, 14-17], but was unclear in 4 studies. Blinding to participants and personnel showed a high risk of bias in all studies. Blinding to outcome assessment showed a high risk of bias in 2 studies [21, 16, 17] and low risk in 1 study [14], but bias was unclear in 7 studies [13, 18, 19, 20, 22, 12, 15]. Other sources of bias were unclear.

Primary endpoints

DASH scores

DASH scores for EF and VLPs were compared at 3, 6, and 12 months in 4 studies. As shown in **Figure 2**, the aggregate results of these studies were divided into 3 subgroups according

Table 3. Range of motion at 3, 6, and 12 months postoperatively

Range of Motion	Number of studies	Mean difference [95% CI]	*P*	Heterogeneity	
				I^2	*P*
3 months					
Flexion	6 [1, 3, 11, 22-25]	-2.20 [-8.29, 3.89]	0.48	99%	<0.001
Extension	6 [1, 3, 11, 22-25]	-9.49 [-16.75, -2.23]	0.01	99%	<0.001
Pronation	6 [1, 3, 11, 22-25]	-2.12 [-7.05, 2.81]	0.4	98%	<0.001
Supination	6 [1, 3, 11, 22-25]	-13.34 [-17.42, -9.26]	0.000	93%	<0.001
Radial deviation	6 [1, 3, 11, 22-25]	-8.61 [-11.93, -5.28]	0.000	98%	<0.001
Ulnar deviation	6 [1, 3, 11, 22-25]	-2.78 [-5.41, -0.16]	0.04	97%	<0.001
6 months					
Flexion	6 [1, 3, 11, 22-25]	-3.52 [-10.62, 3.59]	0.33	99%	<0.001
Extension	6 [1, 3, 11, 22-25]	-9.21 [-18.46, 0.04]	0.05	99%	<0.001
Pronation	6 [1, 3, 11, 22-25]	-10.90 [-31.56, 9.76]	0.3	98%	<0.001
Supination	6 [1, 3, 11, 22-25]	-5.26 [-11.19, 0.67]	0.08	99%	<0.001
Radial deviation	6 [1, 3, 11, 22-25]	-0.68 [-5.08, 3.73]	0.76	97%	<0.001
Ulnar deviation	6 [1, 3, 11, 22-25]	0.70 [-4.02, 5.42]	0.77	96%	<0.001
12 months					
Flexion	6 [1, 3, 11, 22-25]	-1.46 [-6.80, 3.87]	0.59	98%	<0.001
Extension	6 [1, 3, 11, 22-25]	-2.13 [-6.56, 2.30]	0.35	97%	<0.001
Pronation	6 [1, 3, 11, 22-25]	-2.10 [-5.43, 1.22]	0.21	91%	<0.001
Supination	6 [1, 3, 11, 22-25]	-1.87 [-6.52, 2.78]	0.43	97%	<0.001
Radial deviation	6 [1, 3, 11, 22-25]	-0.89 [-3.90, 2.12]	0.56	98%	<0.001
Ulnar deviation	6 [1, 3, 11, 22-25]	-2.28 [-5.14, 0.58]	0.12	96%	<0.001

to the study design. I^2 values for heterogeneity at 3, 6, and 12 months were 99.3% ($P<0.001$), 96.9% ($P<0.001$), and 83.4% ($P<0.001$), respectively. The random-effects model was applied to these studies. DASH scores in the EF group were superior to those in the VLP group at 3 months (WMD=12.13; 95% CI: 1.47-22.79; $P<0.001$) and 6 months (WMD=5.08; 95% CI: -0.03-10.19; $P<0.001$). However, there was no difference between the EF and VLP group at 12 months (WMD=4.70; 95% CI: -1.95-11.35; $P=0.166$).

Range of motion

Range of motion was assessed in 6 studies (**Table 3**). At 3 months, wrist extension in the EF group was less than in the VLP group (MD=-9.49; 95% CI: -16.75--2.23; $P=0.01$). Supination, radial deviation, and ulnar deviation in the EF group were also less than in the VLP group at 3 months (MD=-13.34; 95% CI: -17.42--9.26; $P<0.001$, MD=-8.61; 95% CI: -11.93--5.28; $P<0.001$, and MD=-2.78; 95% CI: -5.41--0.16; $P=0.04$, respectively). Other items showed no differences. Range of motion also showed no difference between EF and VLP groups at 6 and 12 months.

Grip strength

Two studies examined grip strength. The results of comparisons between the EF and VLP groups are shown in **Figure 3**. Grip strength in the EF group at 3 months was significantly lower than that in the VLP group (WMD=-13.60; 95% CI: -23.61--3.59; P<0.001), but the differences were not significantly different at 6 (WMD= -2.77; 95% CI: -11.32-5.78; P=0.526) and 12 months (WMD=-1.98; 95% CI: -7.84-3.88; P=0.507).

Secondary endpoints

We also compared VAS scores, complication rates, and radiological measurements. The VAS scores (**Figure 4**) showed no significant differences between the EF and VLP groups after adopting a random-effects model.

We compared the radiological outcomes in these studies 12 months after surgery and examined whether EF was associated with a higher

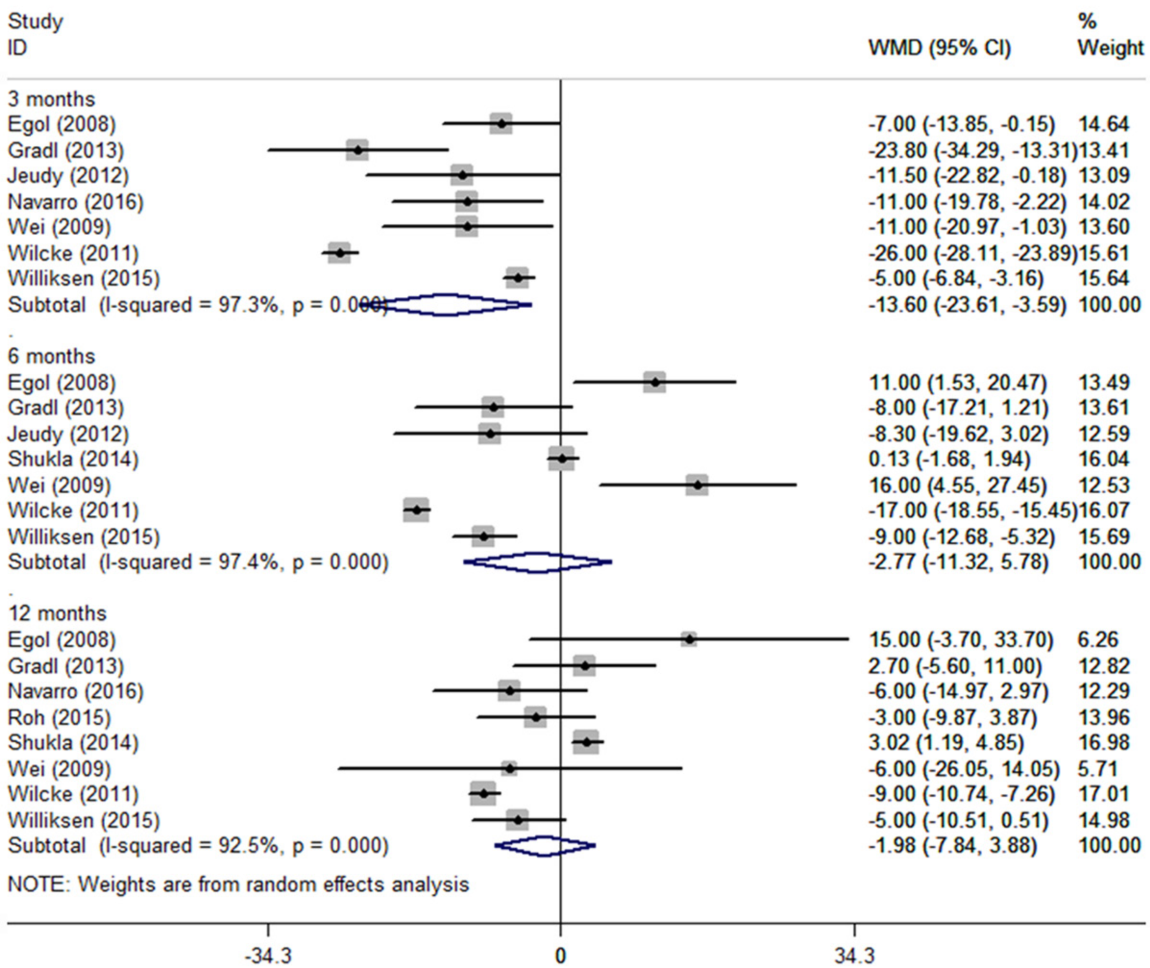

Figure 3. Forest plot comparing grip strength. The EF group showed lower grip strength than the VLP group at 3 months, but there was no difference at 6 or 12 months.

ulnar deviation (MD=0.94; 95% CI: 0.8-1.70; *P*<0.001). The results are shown in **Table 4**.

Complications included wound and pin-track infections, tendon rupture, carpal tunnel syndrome, complex regional pain syndrome, and need for reoperation. We found that patients undergoing EF were much more susceptible to wound and pin-track infection than those undergoing VLP (RR=7.15; 95% CI: 2.36-21.64; *P*=0.0005). However, the reoperation rate was higher for VLP than for EF (RR=0.32; 95% CI: 0.16-0.64; *P*=0.001; **Table 5**).

Publication bias

We also assessed publication bias using grip strength at 12 months. The results showed no publication bias. The Begg test (z=0.62, *P*=0.563; **Figure 5**) and Egger test (t=0.28, *P*=0.788) did not indicate bias.

Discussion

In this meta-analysis, we observed better early postoperative functional outcomes in the VLP group than in the EF group, but no difference between the groups was seen at 1 year. Patients undergoing EF were more likely to develop wound and pin-track infections. Patients in the VLP group had significantly higher grip strength than those in the EF group. However, there was a significantly higher rate of reoperation in the VLP group.

Differences in DASH scores were statistically significant during follow-up. However, the minimal clinically important difference for the DASH score ranged between 10 and 15 points [11]. Therefore, the difference in DASH scores at 3 months after surgery indicated substantial functional improvement [20]. Significantly better results in DASH scores are consistent with

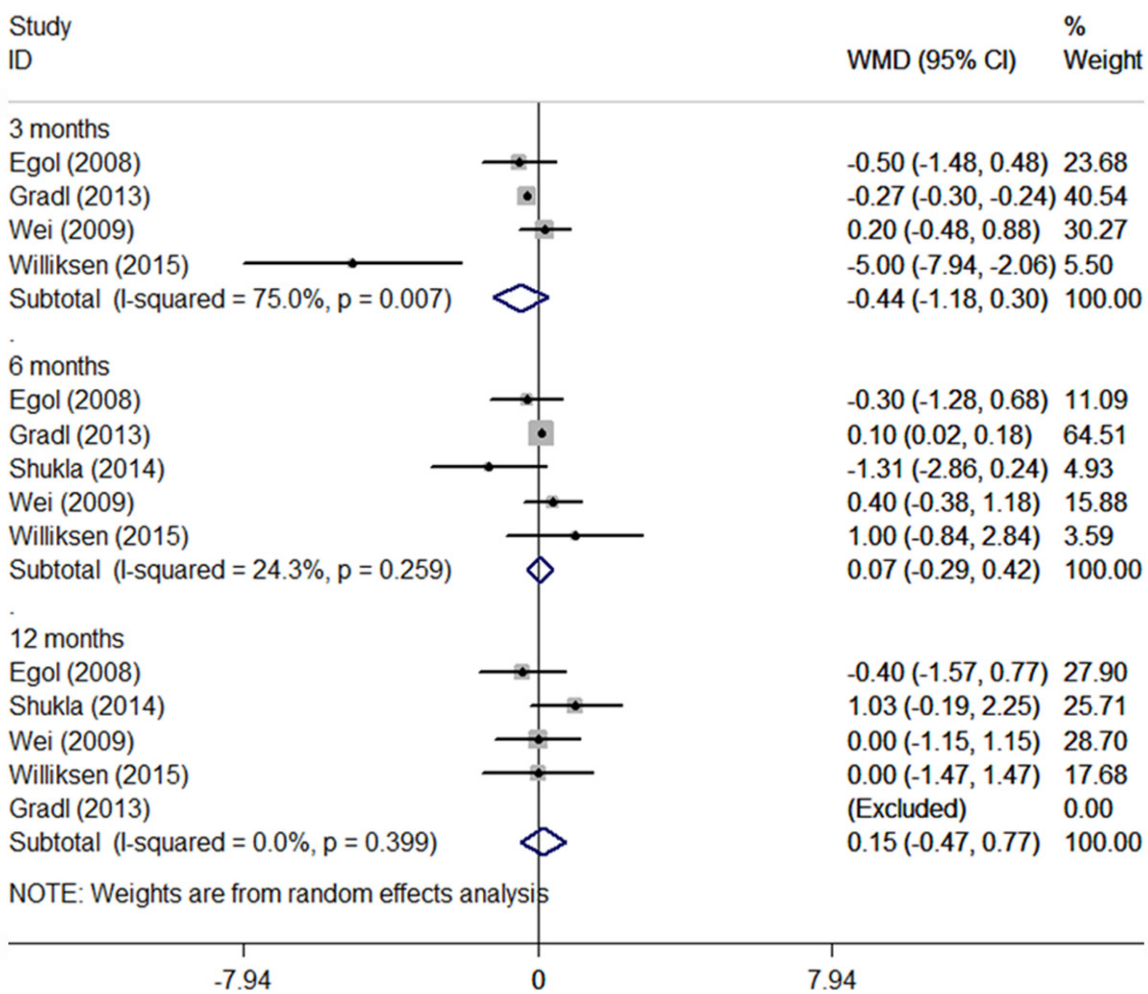

Figure 4. Forest plot comparing VAS scores. The results showed no difference at 3, 6, or 12 months.

Table 4. Radiological measurements

Radiological outcomes	Number of studies	Mean difference [95% CI]	*P*	Heterogeneity	
				I^2	*P*
Radial length	3 [1, 10, 22]	0.40 [-0.51, 1.30]	0.39	53%	0.12
Radial inclination	5 [1, 10, 11, 15, 22]	0.19 [-1.18, 1.55]	0.79	77%	0.002
Ulnar variance	4 [1, 5, 11, 22]	0.94 [0.80, 1.07]	0.000	0%	0.61
Volar tilt	7 [1, 3, 5, 10, 11, 15, 22]	2.40 [-0.37, 5.17]	0.09	100%	<0.001

Table 5. Complications

Complications	Number of studies	RR [95% CI]	*P*	Heterogeneity	
				I^2	*P*
Wound and pin-track infection	5 [1, 3, 10, 11, 23]	7.15 [2.36, 21.64]	0.0005	0%	0.56
Tendon rupture	4 [1, 3, 10, 23]	0.59 [0.17, 1.98]	0.39	0%	0.64
Carpel tunnel syndrome	8 [1, 3, 5, 10, 11, 15, 23-25]	0.72 [0.37, 1.42]	0.34	0%	0.83
Complex regional pain syndrome	7 [3, 5, 11, 15, 19, 23-25]	1.43 [0.89, 2.30]	0.14	0%	0.82
Reoperation	5 [1, 3, 10, 11, 23]	0.32 [0.16, 0.64]	0.001	26%	0.25

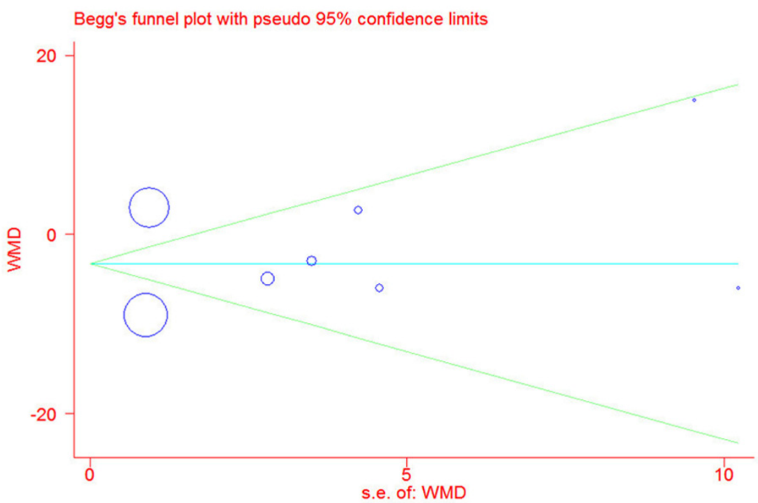

Figure 5. Funnel plot comparing fusion rates for EF and VLP. The y-axis represents WMD, and the x-axis standard error of log (WMD). The dashed line in the middle is the log (WMD) value calculated from the fusion rate. Sloped lines represent the 95% CI boundaries and circles indicate the 7 studies evaluated.

results reported by Walenkamp et al. [11]. As the external fixators were removed after bone healing, the DASH scores were likely to change. The lower DASH score after using VLPs may be associated with worse wrist range of motion exercise [20].

Comparison of functional outcomes between EF and VLPs showed that extension, supination, radial deviation, and ulnar deviation were significantly better in the VLP group than in the EF group at the 3-month follow-up. This may be attributable to functional exercise during the early postoperative period. The change in dynamic grip strength with VLP was larger than with EF in the early postoperative stage and may be helpful in functional exercise. Patients found functional exercises to be inconvenient because of wrist joint limitations caused by EF, which could lead to unsatisfactory outcomes for grip strength and range of motion.

The VAS score is an important indicator but showed no difference between the EF and VLP groups during follow-up. Radiological analysis revealed that EF did not maintain ulnar variance to the same extent as VLPs, similar to reports by other authors [19].

There were more complications in the EF group than in the IF group, mainly wound and pin-track infections. A pin-site infection rate of up to 43% has been reported, but no further treatment was required [23-25]. Quality of life decreased once infections appeared. Except for a higher rate of reoperation in the VLP group, other complications showed no difference. However, other studies [26, 15, 16] were inconclusive. The need for reoperation was mainly due to tendon rupture and carpal tunnel syndrome.

Distal radial fractures have been treated by surgeons using bridging EF in preference to using VLPs, as many surgeons consider EF a familiar technique that requires minimal exposure [27]. Our study included 10 RCTs (11 articles), some of which suggested that use of VLPs led to faster recovery. No difference was observed in functional outcome, radiological findings, and complication rates at 1 year. The need for reoperation was more common with VLP use. Compared with the findings reported by Li [20], other studies showed similar outcomes. Moreover, Li's study included 6 articles, while our study included 10 RCTs.

Our meta-analysis has several potential limitations. First, statistical heterogeneity was large. This may be the result of differences in EF technique, as some studies reported temporary fixation with Kirschner wires. Second, external fixators were removed at different time points, which could have contributed to heterogeneity. External fixators were removed at a minimum of 5 weeks to a maximum of 6 weeks [14]. Third, some patients underwent "pure" EF, while some underwent EF with supplementary K wires. These are two largely different operations. With the use of K wires, EF acts as a neutralization plate whereas, "pure" EF relies on ligamentotaxis. Thus, these results should be cautiously interpreted.

VLP use may improve functional recovery early after surgery in patients with unstable distal radial fractures. However, VLP use and EF showed comparable functional scores 12 months postoperatively. Nonetheless, the results need to be interpreted with caution due to study heterogeneity and various sources of bias. High-quality, large-sample clinical research is needed for further validation.

Acknowledgements

This study was supported by the Social Development Foundation of Shaanxi Province (grant numbers 2017ZDXM-SF-009, 2017SF-050). We thank all colleagues working in the Department of Orthopedic Trauma, Honghui Hospital, Xi'an Jiaotong University.

Disclosure of conflict of interest

None.

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