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 meta-analysis 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

Introduction

There is no consensus on the optimal treatment of distal radius fractures. 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 \(<10^\circ\) (from neutral), loss of height of \(<2\) mm compared with the contralateral side, articular step-off of \(\leq 1\) mm, and no associated instability of the distal radio-ulnar joint. These fractures can be treated nonoperatively with a satisfactory outcome. For unstable types, if fractures can be reducible to an acceptable position by sustained countertraction using the concept of ligamentotaxis, external fixation (EF) (with/without percutaneous Kirschner-wire) 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 and internal fixation with various forms of implants.

In recent decades, internal fixation with volar locking plates (VPs) has become increasingly popular. Theoretically, it can provide robust and satisfactory stability and reduce the damage of the dorsal extensor tendons due to the volar approach. Although different types of fixation and many case series with good results have been published, 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. 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. and Li-hai et al. undertook two...
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, 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. 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). 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. 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. 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 F statistic conforming to PRISMA guidelines. F value <25% was considered homogeneous, F values of 25%, 50%, and 75% or more represent low, moderate, and high heterogeneity, respectively. 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. Sensitivity analyses (exclusion of one study at a time) were
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; \( P = 0.002; F = 77\% \)). Similar significant results were obtained at 6 months (mean difference = −6.20; 95% CI: −9.83 to −2.58; \( P = 0.0008; F = 0\% \)), as well as at 12 months postoperatively (mean difference = −6.39; 95% CI: −11.91 to −0.87; \( P = 0.02; F = 62\% \) [Figure 1].

**Meta-analysis 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; \( P < 0.0001; F = 63\% \)). However, analysis for grip strength revealed no significant difference (mean difference = 3.46; 95% CI: −3.76 to 10.68; \( P = 0.35; F = 81\% \) and mean difference = 3.38; 95% CI: −1.14–7.90; \( P = 0.14; F = 49\% \), 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; \( P = 0.03; F = 57\% \), mean difference = 10.90; 95% CI: 1.50–20.30; \( P = 0.02; F = 79\% \) and mean difference = 4.82; 95% CI: 0.53–9.11; \( P = 0.03; F = 34\% \), 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; \( P = 0.0007; F = 0\% \)). 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; \( P = 0.005; F = 0\% \)) 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%
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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;
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; I² = 0%), whereas no significant difference in moderate and severe complications was detected (RR = 1.12; 95% CI: 0.69–1.82; P = 0.65; I² = 18% and RR = 1.12; 95% CI: 0.60–2.08; P = 0.72; I² = 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.
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.
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 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. 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 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. 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.

References
1. Schneppendahl J, Windolf J, Kaufmann RA. Distal radius fractures: Current concepts. J Hand Surg Am 2012;37:1718-25.
2. Simic PM, Weiland AJ. Fractures of the distal aspect of the radius: Changes in treatment over the past two decades. Instr Course Lect 2003;52:185-95.
3. Jupiter JB. Fractures of the distal radius. Surg Annu 1992;24 (Pt 1):143-60.
4. Siripakarn Y, Siripakarn Z. Multipurpose external fixator for intraarticular fracture of distal radius. J Med Assoc Thai 2010;93 Suppl 7:S324-31.
5. Haddad M, Rubin G, Soudry M, Rozen N. External fixation for the treatment of intraarticular fractures of the distal radius: Short-term results. Isr Med Assoc J 2010;12:406-9.
6. Habenerk H, Weinstabl R, Fialka C, Schmid L. Unstable distal radius fractures treated by modified kirschner wire pinning: Anatomic considerations, technique, and results. J Trauma 1994;36:83-8.
7. Kamiloski V, Kasapinova K. External fixation in patients with age over 65 years with distal radius fracture. Prilozi 2006;27:189-99.
8. Dicpinigaitis P, Wolinsky P, Hiebert R, Ego K, Koval K, Tejwani N, et al. Can external fixation maintain reduction after distal radius fractures? J Trauma 2004;57:845-50.
9. Nishiwaki M, Tazaki K, Shimizu H, Ilyas AM. Prospective study of distal radial fractures treated with an intramedullary nail. J Bone Joint Surg Am 2011;93:1436-41.
10. Kawasaki K, Nemoto T, Inagaki K, Tomita K, Ueno Y. Variable-angle locking plate with or without double-tiered subchondral support procedure in the treatment of intraarticular distal radius fracture. J Orthop Traumatol 2014;15:271-4.
11. Wong KK, Chan KW, Kwok TK, Mak KH. Volar fixation of dorsally displaced distal radial fracture using locking compression plate. J Orthop Surg (Hong Kong) 2005;13:153-7.
12. Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: A preliminary report. J Hand Surg Am 2002;27:205-15.
13. Kandemir U, Matityahu A, Desai R, Puttlitz C. Does a volar locking plate provide equivalent stability as a dorsal nonlocking plate in a dorsally comminuted distal radius fracture? A biomechanical study. J Orthop Trauma 2008;22:605-10.
14. Missakian ML, Cooney WP, Amadio PC, Glidewell HL. OPEN reduction and internal fixation for distal radius fractures. J Hand Surg Am 1992;17:745-55.
15. Rikli DA, Küberf K, Bodoky A. Long term results of the external fixation of distal radius fractures. J Trauma 1998;44:970-6.
16. Young BT, Rayan GM. Outcome following nonoperative treatment of displaced distal radius fractures in low-demand patients older than 60 years. J Hand Surg Am 2000;25:19-28.
17. Margaliot Z, Haase SC, Kotsis SV, Kim HM, Chung KC. A meta-analysis of outcomes of external fixation versus plate osteosynthesis for unstable distal radius fractures. J Hand Surg Am 2005;30:1185-99.
18. Cui Z, Pan J, Yu B, Zhang K, Xiong X. Internal versus external fixation for unstable distal radius fractures: An up-to-date meta-analysis. Int Orthop 2011;35:1333-41.
19. Wang J, Yang Y, Ma J, Xing D, Zhu S, Ma B, et al. Open reduction and internal fixation versus external fixation for unstable distal radial fractures: A meta-analysis. Orthop Traumatol Surg Res 2013;99:321-31.
20. Xie X, Xie X, Qin H, Shen L, Zhang C. Comparison of internal and external fixation of distal radius fractures. Acta Orthop 2013;84:286-91.
21. Walenkamp MM, Bentohami A, Beerenkamp MS, Peters RW, van der Heiden R, Goslings JC, et al. Functional outcome in patients with unstable distal radius fractures, volar locking plate versus external fixation: A meta-analysis. Strategies Trauma
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Intraarticular fractures of the distal radius evaluated by computed tomography. J Hand Surg Am 2011;36:1798-803.

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Bridging external fixation and supplementary Kirschner-wire fixation versus volar locked plating for unstable fractures of the distal radius: A randomised, prospective trial. J Bone Joint Surg Br 2008;90:1214-21.

Wicke MK, Abbaszadegan H, Adolphson PY. Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year. Acta Orthop 2011;82:76-81.

Gradi G, Gradi G, Wendt M, Mittelmeier T, Kundt G, Jupiter JB, et al. Non-bridging external fixation employing multiplanar K-wires versus volar locked plating for dorsally displaced fractures of the distal radius. Arch Orthop Trauma Surg 2013;133:595-602.

Williksen JH, Frihagen F, Hellund JC, Kverno MD, Husby T. Volar locking plates versus external fixation and adjuvant pin fixation in unstable distal radius fractures: A randomized, controlled study. J Hand Surg Am 2013;38:1469-76.

Wei DH, Raizman NM, Bottino CJ, Jobin CM, Strauch RJ, Rosenwasser MP, et al. Unstable distal radial fractures treated with external fixation, a radial column plate, or a volar plate. A prospective randomized trial. J Bone Joint Surg Am 2009;91:1568-77.

Jeudy J, Steiger V, Boyer P, Cronier P, Bizot P, Massin P, et al. Treatment of complex fractures of the distal radius: A prospective randomised comparison of external fixation ‘versus’ locked volar plating. Injury 2012;43:174-9.

Knirk JL, Jupiter JB. Intraarticular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am 1986;68:647-59.

Kredel HJ, Hanel DP, McKee M, Jupiter J, McGillivary G, Swiontkowski MF, et al. X-ray film measurements for healed distal radius fractures. J Hand Surg Am 1996;21:31-9.

Kawaguchi S, Sawada K, Nabeta Y, Hayakawa M, Aoki M. Recurrent dorsal angulation of the distal radius fracture during dynamic external fixation. J Hand Surg Am 1998;23:920-5.

Turner RG, Faber KJ, Athwal GS. Complications of distal radius fractures. Hand Clin 2010;26:85-96.

Tanabe K, Nakajima T, Sogo E, Denno K, Horiki M, Nakagawa R, et al. Intraarticular fractures of the distal radius evaluated by computed tomography. J Hand Surg Am 2011;36:1798-803.

Harness NG, Jupiter JB, Orbay JL, Raskin KB, Fernandez DL. Loss of fixation of the volar lunate facet fragment in fractures of the distal part of the radius. J Bone Joint Surg Am 2004;86-A:1900-8.