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Systematic Review or Meta-analysis

What Is the Relative Effectiveness of the Various Surgical Treatment Options for Distal Radius Fractures? A Systematic Review and Network Meta-analysis of Randomized Controlled Trials

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Abstract

Background Many acceptable treatment options exist for distal radius fractures (DRFs); however, a simultaneous comparison of all methods is difficult using conventional study designs.
Questions/purposes We performed a network meta-analysis of randomized controlled trials (RCTs) on DRF treatment to answer the following questions: Compared with nonoperative treatment, (1) which intervention is associated with the best 1-year functional outcome? (2) Which intervention is associated with the lowest risk of overall complications? (3) Which intervention is associated with the lowest risk of complications requiring operation?
Methods Ten databases were searched from inception to July 25, 2019. Search and analysis reporting adhered to

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Each author certifies that his or her institution waived approval for the reporting of this investigation and that all investigations were conducted in conformity with ethical principles of research.
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Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. Included studies were English-language RCTs that assessed at least one surgical treatment arm for adult patients with displaced DRFs, with less than 20% loss to follow-up. We excluded RCTs reporting on patients with open fractures, extensive bone loss, or ipsilateral upper extremity polytrauma. Seventy RCTs (n = 4789 patients) were included. Treatments compared were the volar locking plate, bridging external fixation, nonbridging external fixation, dynamic external fixation, percutaneous pinning, intramedullary fixation, dorsal plating, fragment-specific plating, and nonoperative treatment. Subgroup analyses were conducted for intraarticular fractures, extraarticular fractures, and patients with an average age greater than 60 years. Mean (range) patient age was 59 years (56 to 63) and was similar across all treatment groups except for dynamic external fixation (44 years) and fragment-specific plating (47 years). Distribution of intraarticular and extraarticular fractures was approximately equal among the treatment groups other than that for intramedullary fixation (73% extraarticular), fragment-specific plating (66% intraarticular) [13, 70], and dorsal plating (100% intraarticular). Outcomes were the DASH score at 1 year, total complications, and reoperation. The minimum clinically important different (MCID) for the DASH score was set at 10 points. The analysis was performed using Bayesian methodology with random-effects models. Rank orders were generated using surface under the cumulative ranking curve values. Evidence quality was assessed using Grades of Recommendation, Assessment, Development and Evaluation (GRADE) methodology. Most studies had a low risk of bias due to randomization and low rates of incomplete follow-up, unclear risk of bias due to selective reporting, and high risk of bias due to lack of patient and assessor blinding. Studies assessing bridging external fixation and/or nonoperative treatment arms had a higher overall risk of bias while studies with volar plating and/or percutaneous pinning treatment arms had a lower risk of bias.

Results Across all patients, there were no clinically important differences in terms of the DASH score at 1 year; although differences were found, all were less than the MCID of 10 points. Volar plating was ranked the highest for DASH score at 1 year (mean difference -7.34 [95% credible interval -11 to -3.7) while intramedullary fixation, with low-quality evidence, also showed improvement in DASH score (mean difference -7.75 [95% CI -14.6 to -0.56]). The subgroup analysis revealed that only locked volar plating was favored over nonoperative treatment for patients older than 60 years of age (mean difference -6.4 [95% CI -11 to -2.1]) and for those with intraarticular fractures (mean difference -8.4 [95% CI -15 to -2.0]). However, its clinical importance was uncertain as the MCID was not met. Among all patients, intramedullary fixation (odds ratio 0.09 [95% CI 0.02 to 0.84]) and locked volar plating (OR 0.14 [95% CI 0.05 to 0.39]) were associated with a lower complication risk compared with nonoperative treatment. For intraarticular fractures, volar plating was the only treatment associated with a lower risk of complications than nonoperative treatment (OR 0.021 [95% CI < 0.01 to 0.50]). For extraarticular fractures, only nonbridging external fixation was associated with a lower risk of complications than nonoperative treatment (OR 0.011 [95% CI < 0.01 to 0.65]), although the quality of evidence was low. Among all patients, the risk of complications requiring operation was lower with intramedullary fixation (OR 0.06 [95% CI < 0.01 to 0.85) than with nonoperative treatment, but no treatment was favored over nonoperative treatment when analyzed by subgroups.

Conclusion We found no clinically important differences favoring any surgical treatment option with respect to 1-year functional outcome. However, relative to the other options, volar plating was associated with a lower complication risk, particularly in patients with intraarticular fractures, while nonbridging external fixation was associated with a lower complication risk in patients with extraarticular fractures. For patients older than 60 years of age, nonoperative treatment may still be the preferred option because there is no reliable evidence showing a consistent decrease in complications or complications requiring operation among the other treatment options. Particularly in this age group, the decision to expose patients to even a single surgery should be made with caution.

Level of Evidence Level I, therapeutic study.

Introduction

Although closed reduction and casting is often the treatment of choice for stable, nondisplaced fractures, operative fixation is recommended for displaced or unstable distal radius fractures (DRFs) [8]; there is concern for functional limitations if they are left untreated beyond 4 weeks [73, 78, 95, 113]. Fixed-angle volar plating is the most common method of internal fixation for displaced DRFs and is preferred by nearly 85% of hand and wrist surgeons [105]. Other methods of surgical fixation include bridging or nonbridging external fixation, percutaneous pinning, dorsal plating, fragment-specific plating, and intramedullary fixation. The fixation choice is largely guided by patient and fracture characteristics; however, surgeon preference continues to play a large role in this decision, and the superiority of one method to another continues to be contentious [14, 64, 73].

There is a relative abundance of studies exploring DRF treatment, including numerous meta-analyses of pooled data from randomized controlled trails (RCTs) (Supplemental Digital Content 1; http://links.lww.com/CORR/A441). Many pairwise comparisons have been made including internal and external fixation [125, 126, 128, 134, 135, 137], dynamic or nonbridging and static external fixation [20, 41, 86], volar locking plates and external fixation [26, 32, 74, 122, 123], volar locking plates and percutaneous K-wires [4, 17, 30, 108, 109, 136, 140], and volar locking plates and intramedullary fixation [139]. Important between-study differences have been identified, including subtle differences in functional outcomes and complication profiles [23, 127]. Unfortunately, all traditional meta-analyses can only compare two treatment options at a time, thereby excluding large numbers of studies regarding DRF treatment. In addition, we have observed that not all contemporary treatment approaches have been compared head to head in RCTs, preventing the inclusion of these approaches in traditional meta-analyses. Multiarm RCTs have been performed, but they are limited by sample size, and comparing all potential treatment arms in one trial would be impractical [3, 23, 126]. Ultimately, despite the number of RCTs and meta-analyses, no consensus has been reached by major orthopaedic and hand surgery associations on the ideal DRF treatment [14, 73].

Considering the limitations of existing studies, a network meta-analysis (NMA) offers several advantages [58]. Unlike a traditional direct meta-analysis, an NMA leverages direct and indirect comparisons using network relationships of common treatment arms [16, 28, 38, 119]. The relative effect of treatments that have not been directly compared, or directly compared in only a few studies, can be estimated using a common comparator, such as nonoperative treatment [28, 121]. This facilitates the inclusion of outcome data from nearly all published RCTs on the treatment of DRFs in the final analysis, thereby generating more-complete, evidence-based effect estimates of treatment.

Therefore, we asked the following questions: Compared with nonoperative treatment, (1) which intervention is associated with the best 1-year functional outcome? (2) Which intervention is associated with the lowest risk of overall complications? (3) Which intervention is associated with the lowest risk of complications requiring surgery?

Materials and Methods

Search Strategy

This systematic review and NMA was conducted in compliance with the Cochrane Handbook for Systematic Reviews of Interventions [47] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for NMAs [54, 87] (Supplemental Digital Content 2; http://links.lww.com/CORR/A442). We comprehensively searched 10 electronic databases to identify relevant RCTs, including MEDLINE, Embase, Cumulative Index to Nursing & Allied Health Literature (CINAHL), Web of Science, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Latin American and Caribbean Center on Health Sciences Information, Physiotherapy Evidence Database, the WHO's International Clinical Trials Registry Platform, and ClinicalTrials.gov. Search terms were generated through consultation with clinical epidemiologists (AK, HJ) (Supplemental Digital Content 2; http://links.lww.com/CORR/A442). The unaltered study protocol is available for reference (Supplemental Digital Content 3; http://links.lww.com/CORR/A443).

Selection Criteria

Inclusion criteria were RCTs with two or more treatment arms, at least one of which involved a surgical intervention. We selected English-language studies with adult patients (age 18 years or older) with DRF that were published either as a full-text article or abstract. Minimum follow-up duration was 3 months. The included surgical interventions were determined before the study search. Treatment groups included a volar locking plate, bridging external fixation, nonbridging external fixation, dynamic external fixation, percutaneous pinning (any technique), intramedullary fixation, dorsal plating, fragment-specific plating, and nonoperative treatment. Nonoperative treatment, a common control group, was defined as below-elbow plate or fiberglass casting for a duration meeting the standard of care according to the authors' respective institutions, typically 30 to 45 days. We included trials reporting any of our predetermined outcomes of interest and excluded trials solely comparing implant properties or variations in treatment application. If multiple studies reported on the same outcomes for the same patient population, we included only the most recent publication. However, if different outcomes of interest or different timepoints were reported, we included both studies. We excluded studies if nonrandom loss to follow-up was > 20% [66]. In addition, we excluded trials from the quantitative analysis if they involved patients who had open fractures, extensive bone loss, or ipsilateral upper extremity polytrauma. There was no restriction on publication date. Observational studies, case series, case reports, biomechanical cadaver studies, basic science studies, review articles, correspondence, and comments were excluded.

Screening

The search was completed on July 25, 2019. The search was augmented by a manual review of references from included studies and relevant systematic reviews. Studies were screened using Mendeley (Version 1.19.3, Mendeley Limited, London, UK). Three teams of two reviewers each (TW, AK, FK, LG, JG, KG) screened all titles, abstracts, and full-text articles independently and in duplicate. Discrepancies were resolved by automatic inclusion at the title and abstract stages and by involvement of a senior author (HJ) at the full-text stage.

Outcomes of Interest

The outcomes of interest were as follows: (1) functional score: DASH score at 1 year postoperatively [129]. The minimum clinically important difference (MCID) was established as 10 points based on published values [31]. (2) Complications: major listed complications including infection, complex regional pain syndrome, tenosynovitis, tendon rupture, tendinitis, and nerve injury. (3) Risk of complication requiring surgery, including any need for surgery after the index procedure and excluding planned external fixation or pin removal. For surgical treatment options, this constitutes reoperation, and for all patients, an unplanned operation. Considering functional outcome, we chose to use the DASH score alone as it is the most commonly reported quantitative functional score in the DRF literature. Considering that the DASH was published in 1996, studies predating this time were excluded from the functional analysis. Although many different scores have been used, this decision was made to avoid the potential pitfalls of combining functional scores.

Data Extraction

Data were abstracted in duplicate by a team of four reviewers (TW, LG, JG, KG) using a piloted extraction document (Microsoft Excel 16.2, Redmond, WA, USA), which was designed a priori. Discrepancies were resolved through consultation with a fifth reviewer (HJ). Abstracted data included country of origin, RCT methods, patient demographics, fracture pattern, treatment details, follow-up duration, and loss to follow-up. Routine removal of percutaneous K-wires and/or external fixation pins was not recorded as a reoperation, while removal of internal hardware (such as screws) qualified as a complication requiring operation. Means and standard deviations were collected; medians were used in lieu of means if mean values were not available [93]. If a 95% confidence interval was reported as the measure of variability, the SD was approximated [48]. When no measure of variance was reported, the SD was imputed using a p value or a weighted average of variances observed in other included studies [48, 77].

Quality Assessment

The quality of each included study was evaluated in duplicate using the Cochrane Risk of Bias tool, and the Cochrane Confidence in Network Meta-Analysis (CINeMA) tool was used for the risk of bias assessment specific to NMAs [18, 46]. Risk of bias domains were rated according to predefined criteria (Supplemental Digital Content 2; http://links.lww.com/CORR/A442). Of note, loss to follow-up less than 5% was considered low risk of bias, while loss great than 20% was considered to pose a high risk of bias. Disagreement was resolved through consultation with the senior author (HJ). The overall quality of the evidence was determined and ranked per the Grades of Recommendation, Assessment, Development and Evaluation approach for NMAs [43, 97].

Study Characteristics

The final search identified 16,724 studies; 223 studies underwent full-text review, of which 75 were included in the systematic review and 70 (n = 4789 patients) in the NMA (Fig. 1). Included studies were published between 1989 and 2019. Reflecting trends in surgical technique, most studies involving volar plating [6, 11, 19, 23, 24, 33, 37, 39, 40, 49, 59, 60, 63, 71, 79, 81, 82, 89, 90, 92, 98, 102, 104, 106, 110, 117, 131, 132] or intramedullary fixation [15, 35, 36, 94, 107, 138] (87% and 89%, respectively) were published since 2010, while approximately half of all studies involving external fixation [1, 2, 5, 7, 27, 44, 45, 50-52, 55, 61, 62, 65, 67-69, 83, 88, 99-101, 111, 134] or percutaneous fixation [3, 4, 9, 10, 12, 42, 72, 75, 80, 84, 96, 103, 114, 115, 120, 130, 133] (56% and 44%, respectively) were published before 2010 (Supplemental Digital Content 4; http://links.lww.com/CORR/A444). Studies included 19 unique pairwise comparisons. Two studies had three treatment arms. Fifty-three percent (37 of 70) of studies had a mean patient age older than 60 years, while 74% of all patients (3543 of 4789) were female (Table 1). Follow-up was 12 months or longer in all studies (median [range] 24 months [12 to 240]) and sample sizes were typically small (median [range] 61 patients [9 to 231]). Twenty-four percent (17 of 70) of studies only included intraarticular fractures, while 24% (17 of 70) only included extraarticular fractures (Supplemental Digital Content 4; http://links.lww.com/CORR/A444).

Study Quality

Most studies had a low risk of randomization bias, low or unclear risk of allocation bias, and low risk of bias secondary to low rates of incomplete follow-up (Fig. 2). The risk of bias because of selective reporting and other factors was largely unclear. Because of the nature of surgical management, blinding of patients and outcome assessors was largely infeasible, and thus the risk of

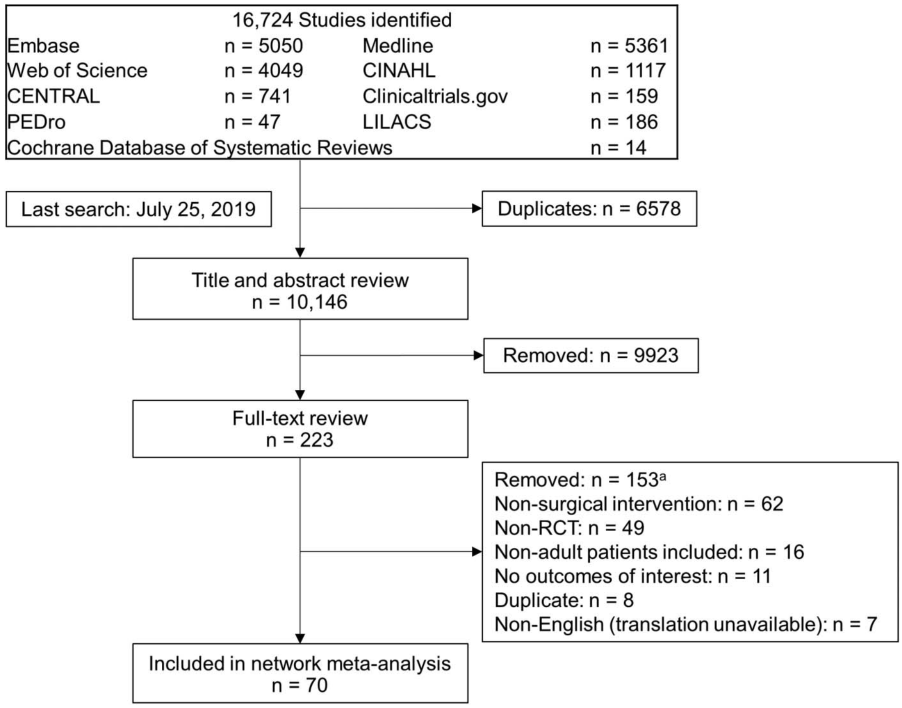

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for study screening. [a]Five studies examined novel interventions or modifications of interventions that were not found in other studies and were therefore excluded from the network meta-analysis.

performance and detection bias was high in most studies. Studies including bridging external fixation and/or nonoperative treatment arms had a higher overall risk of bias, with 23% (7 of 31) and 21% (5 of 24) of studies at high risk of bias, respectively. Studies including volar plating and/or percutaneous pinning treatment arms had a lower risk, with only 6% (2 of 36) and 6% (1 of 17) of studies being rated as having a high risk of bias, respectively.

Statistical Analysis

Statistical analysis was performed using RevMan 5.3 (Cochrane, London, UK), GraphPad Prism 8.2.0 (GraphPad Software, San Diego, CA, USA), and R 3.4.2 (Open Access Online). The NMA was conducted using Bayesian random-effects modeling, which is frequently used to analyze data with statistical heterogeneity [77, 118]. Noninformative priors were used. Prior distributions

Table 1. Network patient and fracture characteristics

					Fracture Pattern		
Treatment group	Patients, number	Treatment arms, number	Mean age in years (range)	% female	Intraarticular	Extraarticular	Not specified
Volar locking plate	1441	36	62 (36 to 80)	79	683 (47)	566 (39)	192 (13)
Bridging external fixation	910	31	56 (39 to 74)	70	476 (49)	308 (32)	180 (19)
Percutaneous pinning	843	17	59 (41 to 73)	76	235 (28)	364 (43)	244 (29)
Nonoperative	810	24	61 (32 to 78)	75	355 (44)	455 (56)	0 (0)
Intramedullary fixation	285	10	60 (48 to 72)	77	30 (11)	209 (73)	46 (9)
Nonbridging external fixation	212	8	63 (62 to 64)	79	45 (21)	91 (43)	76 (36)
Dynamic external fixation	127	4	44 (34 to 54)	48	49 (39)	40 (31)	38 (30)
Fragment-specific plating	97	6	47 (24 to 60)	75	64 (66)	9 (9)	24 (25)
Dorsal plate	64	3	59 (45 to 74)	61	64 (100)	0 (0)	0 (0)

For fracture pattern, values are number of patients with proportion listed in parentheses.

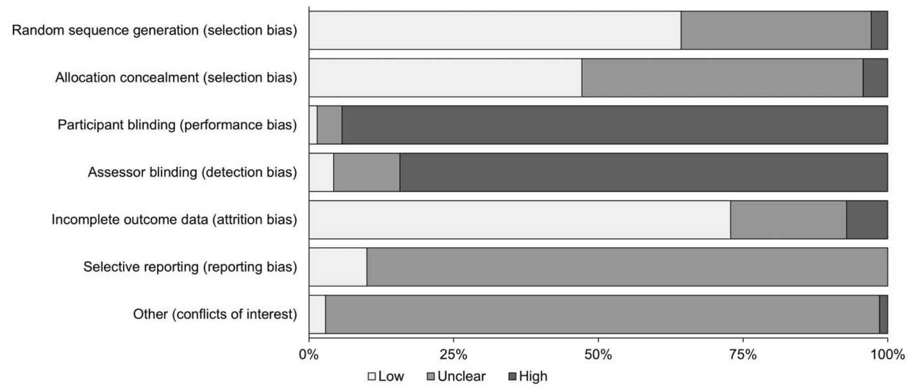

Fig. 2 Risk of bias for the included studies.

describe the uncertainty about a given effect measure. When using noninformative priors, all values in the plausible range of outcomes are assumed to have an equal likelihood of occurrence and only data from included studies are used during analysis [58, 118]. Using noninformative priors avoids introducing subjectivity and/or nonrandomized data into the analysis models. Trials with three or more arms were addressed by the statistical package without manipulation. Ranking diagrams, forest plots, and graphical frameworks were created for each outcome. Surface under the cumulative ranking curve (SUCRA) values were reported for each treatment group. The SUCRA score represents the likelihood that a given treatment will rank first in a specific category; a score closer to 1 indicates that treatment is more likely to represent the best treatment. Global inconsistency across each network model was described using the I^2 value, representing the variation percentage across studies because of study heterogeneity. Incoherence (inconsistency between direct and indirect evidence) was assessed globally using the design-by-treatment interaction test and for individual comparisons using the Separating Indirect from Direct Evidence and node-splitting methods [21, 130]. Global network heterogeneity was moderate for DASH (I^2 50%), substantial for complications (I^2 77%), and moderate for complications requiring operation (I^2 50%).

We conducted a subgroup analysis using three primary subgroups: (1) studies of intraarticular fractures only, (2) studies of extraarticular fractures only, and (3) studies with an average patient age older than 60 years. Interventions were included in the subgroup analysis if data for that intervention were available from at least two independent trials. For all outcomes, a meta-regression analysis was performed to determine whether the age of the included patients affected the pooled treatment estimates. Sensitivity analysis was conducted to determine whether inclusion of studies with less than 1-year follow-up influenced findings regarding complications or complications requiring operation; this was done by repeating the primary outcome analyses after excluding studies with less than 1-year follow-up.

The results of the network for DASH scores are reported as mean differences (MD) with 95% credible intervals. The MCID for DASH scores was established at 10 points, representing the best-available studies [31, 112]. Only studies reported after the publication of the DASH (1996) were included in the functional analysis [53]. Complications and complications requiring surgery are presented using odds ratios and 95% CIs, which were derived using the posterior distribution of the outcome in question and can be thought of as the Bayesian equivalent of confidence intervals. For studies that reported more complications than patients in a treatment arm, the value was set as equal to the sample size. For studies with the highest rate of complications, the network estimates will underestimate the true value. Comparisons were inferred to be statistically significant if the 95% CI of the MD did not cross 0 or if the 95% CI of the OR did not cross one. The number needed to treat was calculated using patient-expected event rates—the weighted average event rates for nonoperative treatment in each respective subgroup.

Results

Functional Outcomes (DASH Score) at 1 Year

There were no clinically important differences in terms of the DASH score at 1 year; although there were differences observed, all were lower than the MCID of 10 points (Table 2). Among all patients, volar plating was ranked the highest by the network (35 RCTs; MD -7.34 [95% CI -11 to -3.7]; SUCRA 0.86) (Supplemental Digital Content 5; http://links.lww.com/CORR/A445). In the intraarticular fracture subgroup (10 RCTs), volar plating was the only treatment associated with less disability at 1 year (MD -8.4

Table 2. GRADE summary table for DASH score at 1 year

Group	Rank	Intervention	Mean difference (95% CI)	Quality of evidence
All patients	1	Volar locking plate	-7.3 (-11 to -3.7)[a]	Moderate[b]
	2	Intramedullary fixation	-7.8 (-14.6 to -0.56)[a]	Very low[b,c]
Intraarticular	1	Bridging external fixation	-14 (-32 to 4.8)	Very low[c,d]
	2	Fragment-specific plating	-11 (-25 to 2.0)	Low[c]
	3	Volar locking plate	-8.4 (-15 to -2.0)[a]	Moderate[e]
Extraarticular	1	Volar locking plate	-4.6 (-10 to 1.4)	Low[d,f]
	2	Nonbridging external fixation	-6.0 (-15 to 3.1)	Very low[c,e]
Average age older than 60 years	1	Volar locking plate	-6.4 (-11 to -2.1)[a]	Moderate[b]
	2	Percutaneous pinning	-7.3 (-22 to 7.1)	Very low[b,c,e]

[a]Inferred to be statistically significant with a 95% CI for mean difference not crossing zero.
[b]Downgraded for indirectness.
[c]Downgraded two levels for imprecision.
[d]Downgraded for risk of bias.
[e]Downgraded for inconsistency.
[f]Downgraded for imprecision.
Mean differences are relative to nonoperative treatment; rank based on SUCRA value; small sample size was considered in the evaluation of imprecision; MCID for DASH is 10 points; GRADE = Grading of Recommendations Assessment, Development and Evaluation.

[95% CI -15 to -2]) compared with nonoperative treatment (Supplemental Digital Content 6; http://links.lww.com/CORR/A446). For these patients, bridging external fixation (MD -14 [95% CI -32 to 4.8]; SUCRA 0.80) was ranked the highest but the estimate was imprecise. No studies involved treatment of exclusively intraarticular fractures with either dynamic external fixation, nonbridging external fixation, or intramedullary fixation. In the subgroup of studies with an average patient age of 60 years or older (seven RCTs), volar plating still ranked the highest and was the only treatment associated with DASH scores better than nonoperative treatment (MD -6.4 [95% CI -11 to -2.1]; SUCRA 0.76) (Supplemental Digital Content 7; http://links.lww.com/CORR/A447).

Complications

Among all patients, intramedullary fixation, nonbridging external fixation, and volar plating were associated with fewer overall complications than nonoperative treatment (Table 3). In the network including all patients, (65 RCTs, Fig. 3) intramedullary fixation (OR 0.09 [95% CI 0.02 to 0.48]; SUCRA 0.89) was ranked highest (Supplemental Digital Content 8; http://links.lww.com/CORR/A448). The sensitivity analysis demonstrated that these findings were consistent when excluding studies involving only patients older than 60 years of age. The subgroup analysis of intraarticular fractures (18 RCTs) revealed that volar plating (OR 0.02 [95% CI < 0.01 to 0.50]; SUCRA 0.74) was the only treatment associated with a lower risk of complication than nonoperative treatment (Supplemental Digital Content 9; http://links.lww.com/CORR/A449). In the extraarticular subgroup (18 RCTs), only nonbridging external fixation (OR 0.01 [95% CI < 0.01 to 0.65]; SUCRA 0.95) was associated with a lower risk of complications than nonoperative treatment; it was ranked the highest by the network. In the subgroup of studies with average patient age older than 60 years (29 RCTs), there was no difference in the risk of complications between nonoperative treatment and any operative intervention (Supplemental Digital Content 10; http://links.lww.com/CORR/A450). Sensitivity analysis demonstrated that including studies with less than 1 year of follow-up did not influence findings.

Risk of Complications Requiring Operation

Among all patients, intramedullary fixation, nonbridging external fixation, bridging external fixation, and percutaneous pinning were associated with a lower risk of complications requiring operation than nonoperative treatment, with intramedullary fixation (OR 0.06 [95% CI < 0.01 to 0.85]; SUCRA 0.89) being ranked highest by the network (Supplemental Digital Content 11; http://links.lww.com/CORR/A451). In the intraarticular subgroup (15 RCTs), there was no difference in the risk of complications requiring operation between any surgical intervention and nonoperative treatment (Supplemental Digital Content 12; http://links.lww.com/CORR/A452); percutaneous pinning (OR 0.09 [95% CI < 0.01 to 5.3];

Table 3. GRADE summary table for risk of complications

Group	Rank	Intervention	Odds ratio (95% CI)	NNT	Quality of evidence
All patients	1	Intramedullary fixation	0.089 (0.02 to 0.84)[a]	3	Low[b,c]
	2	Volar locking plate	0.14 (0.05 to 0.39)[a]	3	Moderate[c,d]
	3	Nonbridging external fixation	0.16 (0.02 to 0.92)[a]	3	Low[c,e]
Intraarticular	1	Percutaneous pinning	0.015 (< 0.01 to 1.1)	2	Low[e]
	2	Volar locking plate	0.021 (< 0.01 to 0.50)[a]	2	Moderate[d]
Extraarticular	1	Nonbridging external fixation	0.011 (< 0.01 to 0.65)[a]	6	Low[e]
	2	Intramedullary fixation	0.10 (< 0.01 to 1.2)	7	Low[c,d]
Average age older than 60 years	1	Dorsal plate	0.076 (< 0.01 to 3.0)	4	Very low[c,e,f]
	2	Intramedullary fixation	0.13 (0.01 to 1.7)	4	Very low[b,c,d]

[a]Inferred to be statistically significant with a 95% CI for mean difference not crossing zero.
[b]Downgraded for inconsistency.
[c]Downgraded for indirectness.
[d]Downgraded for imprecision.
[e]Downgraded two levels for imprecision.
[f]Downgraded for risk of bias.
Odds ratios are relative to nonoperative treatment; rank based on SUCRA value; small sample size was considered in the evaluation of imprecision; GRADE = Grading of Recommendations Assessment, Development and Evaluation; NNT = number needed to treat.

SUCRA 0.83) was ranked the highest by the network. In the extraarticular subgroup (16 RCTs), there was no difference in the risk of complications requiring operation between any surgical intervention and nonoperative treatment; intramedullary fixation (OR 0.02 [95% CI < 0.01 to 2.7]; SUCRA 0.79) was ranked the highest (Table 4). After excluding studies exclusively enrolling patients older than 60 years of age (43 RCTs remaining), all interventions except dorsal plating [40, 56, 57] and dynamic external fixation were associated with a lower risk of complications requiring operation than nonoperative treatment (Supplemental Digital Content 13; http://links.lww.com/CORR/A453). In this subgroup, nonbridging external fixation (OR 0.01 [95% CI < 0.01 to 0.10]; SUCRA 0.94) was ranked the highest. In the subgroup of studies with an average patient age older than 60 years (22 RCTs), no treatment was associated with a lower risk of complications requiring surgery than nonoperative treatment (Table 4); bridging external fixation (OR 0.03 [95% CI < 0.01 to 3.5]; SUCRA 0.84) was ranked the highest. Sensitivity analysis demonstrated that including studies with less than 1 year of follow-up did not influence findings.

Discussion

The treatment of DRFs remains an area of controversy with many uncertainties, despite the publication of numerous RCTs and meta-analyses. Clinical practice guidelines are inconclusive regarding preferred treatment, partly because of the wide range of accepted treatment options. In this situation, the ability to simultaneously compare multiple treatment arms is advantageous. Therefore, the aim of this study was to conduct an NMA of all available RCT evidence on the treatment of DRFs. We found that overall, there were no clinically important differences in terms of the DASH score at 1 year among all the surgical treatment options; although differences were found, all were less than the MCID of 10 points. Relative to the other options, volar plating was associated with a lower complication risk, particularly in patients with intraarticular fractures, while nonbridging external fixation was associated with a lower complication risk in patients with extraarticular fractures. For patients older than 60 years, nonoperative treatment may still be the preferred option because there is no reliable evidence showing a consistent decrease in complications or complications requiring operation among the other treatment options.

Limitations

Although an NMA can be a powerful tool, care must be taken when interpreting findings. The reliability of findings is largely determined by the volume of evidence for each treatment and the number of intertreatment comparisons [85]. For treatments with small sample sizes, inferences are driven by relatively few comparisons and are therefore lower quality, regardless of the total size of the network [85, 130]; many quality-of-evidence evaluations were downgraded for this reason. Regarding subgroups, prospectively planned subgroup analyses are considered more robust than retrospectively planned analyses [116]. For this

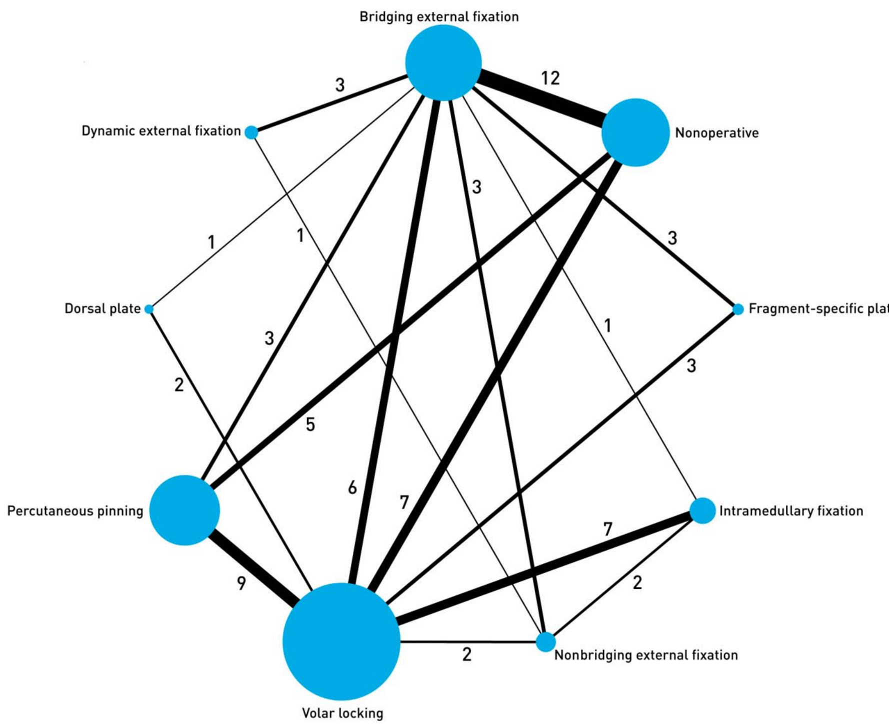

Fig. 3 The network geometry for complications. Node size is proportionate to the number of patients in the specified treatment arm. Line thickness is proportionate to the number of studies. Numbers represent the number of studies directly comparing respective interventions.

analysis, the subgroup of studies with an average patient age older than 60 years was used because there was an insufficient number of studies exclusively on elderly patients. It was not planned a priori and therefore findings from this subgroup may be at greater risk of bias. Further, this subgroup can, at best, act as a weak proxy, because

Table 4. GRADE summary table for risk of complications requiring operation

Group	Rank	Intervention	Odds ratio (95% CI)	NNT	Quality of evidence
All patients	1	Intramedullary fixation	0.06 (< 0.01 to 0.85)[a]	7	Low[b,c]
	2	Volar locking plate	0.17 (0.02 to 1.04)	7	Moderate[b]
	3	Nonbridging external fixation	0.01 (< 0.01 to 0.25)[a]	7	Low[b,d]
	4	Bridging external fixation	0.08 (< 0.01 to 0.60)[a]	7	Low[d,e]
	5	Percutaneous pinning	0.07 (< 0.01 to 0.60)[a]	7	Moderate[d]
Intraarticular	1	Percutaneous pinning	0.09 (< 0.01 to 5.3)	6	Very low[d,f]
	2	Bridging external fixation	0.17 (< 0.01 to 7.2)	6	Very low[d,e,f]
Extraarticular	1	Intramedullary fixation	0.02 (< 0.01 to 2.7)	11	Low[f]
	2	Bridging external fixation	0.10 (< 0.01 to 4.5)	12	Very low[d,f]
Average age older than 60 years	1	Bridging external fixation	0.03 (< 0.01 to 3.5)	7	Low[f]
	2	Intramedullary fixation	0.16 (< 0.01 to 11)	8	Very low[c,f]

[a]Inferred to be statistically significant with a 95% CI for mean difference not crossing zero.
[b]Downgraded for imprecision.
[c]Downgraded for indirectness.
[d]Downgraded for inconsistency.
[e]Downgraded for risk of bias.
[f]Downgraded two levels for imprecision.
Odds ratios are relative to nonoperative treatment; rank based on SUCRA value; small sample size was considered in the evaluation of imprecision; GRADE = Grading of Recommendations Assessment, Development and Evaluation; NNT = number needed to treat.

patients younger than 60 years were included by necessity. The confidence in conclusions from this subgroup should be low and used primarily for generating hypotheses rather than making treatment decisions. Conducting an NMA assumes transitivity, or in the case of surgical treatment for DRF, that interventions have the same indications and can be equally randomized. In certain instances, this assumption is only weakly held. Several interventions included in the present network may have different indications. For example, intramedullary fixation is used more often in patients with extraarticular fractures while dorsal plating [40, 56, 57] is used more often in patients with intra-articular fractures. Conclusions drawn from the entire body of evidence may be influenced by confounding variables that are no longer randomized, and readers should have low confidence in these findings. Subgroups with common treatment indications (age and fracture pattern) are less likely to suffer from this limitation; therefore, network findings may be more reliable.

It is important to consider the sample size underlying each treatment and comparison. Sample size is part of the quality of evidence determination and contributes to imprecision according to GRADE methodology. In several instances, evidence quality was downgraded specifically due to small samples. Findings with low quality evidence are highly likely to be influenced by further research in the form of appropriately powered RCTs. The final notable limitation is the inclusion of studies with follow-up of 3 months (7% [5 of 70 studies]) and six months (14% [10 of 70 studies]). Sensitivity analysis demonstrated that inclusion of these studies did not influence our qualitative results. However, inclusion of these studies may influence the treatment effect size through a small over-representation of short-term complications (such as, infection, neuropathy) over long-term complications (including nonunion, posttraumatic arthritis) [29].

Functional Outcomes (DASH Score) at 1 Year

Across all subgroups, we found no clinically meaningful differences in the DASH score at 1-year between any treatment options. Volar plating, a top-ranked intervention across all subgroups, has previously been associated with improved long-term outcomes over other treatment options, although subsequent studies have found these improvements to be clinically unimportant [17, 25, 34, 136]. Despite being clinically unimportant to the average patient (demonstrated by our study subgroups), some patients may still see a benefit based on variables not accounted for within our broad subgroups. Our findings expand on the existing literature, suggesting that surgical management is unlikely to result in noticeable long-term improvement for most patients relative to nonoperative management, regardless of fracture pattern (that is, intraarticular versus extraarticular) or patient age. However, volar plating has been shown to result in clinically meaningful short-term functional improvements, and this potential benefit should be discussed with patients [34, 98]. Seven studies reported upper extremity functional scores other than DASH (the Mayo Wrist Score, Michigan Hand Questionnaire, and the patient-rated wrist evaluation) and were excluded from the functional analysis. These studies represent a small proportion of total patients, and therefore excluding them is unlikely to substantially influence our findings.

Complications

Across all patients, we found many surgical treatments reduced the complication risk relative to nonoperative treatment, however, the quality of evidence was generally low. In patients with intraarticular fractures, volar plating was associated with a lower complication risk. This finding is consistent with past analyses (which pooled fracture types) and may contribute to a preference for volar plating [105, 136]. Interestingly, we found no surgical treatment was associated with a lower complication risk in older patients. Previous analysis has demonstrated that surgery may in fact be associated with an increased complication risk in this population [9, 28, 124]. Considering this information and our own findings, the benefit of performing surgery in this patient population should be questioned.

Risk of Complications Requiring Operation

We found that most surgical treatment options reduced the risk of complications requiring reoperation when compared with nonoperative management across all patients. However, when analyzed by subgroup, we found no differences between any surgical treatment and nonoperative management. Interestingly, results from our analysis and others showing no difference between treatments differs from large registry data [4, 91, 113]. In a recent registry study of more than 36,000 patients with a mean follow-up of 4.2 years, treatment with a volar locking plate was associated with a greater risk of complications requiring reoperation than external fixation or percutaneous pinning [91]. It may be that most RCTs, and thus meta-analyses, are underpowered and/or have inadequate follow-up to capture differences in reoperation. With respect to patients of advanced age, our findings and the existing literature suggest that surgical intervention, regardless of type, does not reduce the risk of needing further surgery [76]. Therefore, avoiding initial operative management in favor of late intervention, only if necessary, may reduce the overall burden of surgery in these patients.

Conclusion

We found no clinically important differences favoring any surgical treatment option for 1-year functional outcome. However, volar plating was associated with a lower complication risk, particularly in patients with intraarticular fractures, while nonbridging external fixation was associated with a lower complication risk in patients with extraarticular fractures. For patients older than 60 years of age, nonoperative treatment may still be the preferred option because there is no reliable evidence showing a consistent decrease in complications or complications requiring operation among the other treatment options. Particularly in this age group, the decision to expose patients to even a single surgery should be made with caution.

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