EDITOR'S CHOICE

Outcomes of Arthroscopic-Assisted Distal Radius Fracture Volar Plating: A Meta-Analysis

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Purpose The use of wrist arthroscopy to assist fixation of distal radius fractures with volar locking plates (VLPs) has been gaining popularity in recent years; however, there is no consensus on its benefits. This meta-analysis compares outcomes of arthroscopic-assisted VLP to fluoroscopic-assisted VLP in distal radius fractures through a systematic review of the published literature.

Methods A systematic search of publications from databases (Medline, EMBASE, Scopus, and Cochrane) was obtained from inception to May 2020. A random-effects meta-analysis was used to calculate effect sizes. Outcomes included postoperative radiographic reduction (gap, stepoff, radial inclination, volar tilt, and ulnar variance), procedural outcomes (operative time, additional soft tissue injuries and complications), and functional outcomes (range of motion; visual analog scale score; Disabilities of the Arm, Shoulder, and Hand score; Patient-Rated Wrist Evaluation score; Mayo clinic score; and grip strength).

Results Six studies, involving 280 patients, met the final inclusion criteria. The meta-analysis for postoperative stepoff was statistically significant, favoring arthroscopic-assisted VLP. In addition, there was greater identification of associated soft tissue injuries, increased wrist extension, and a longer operative duration when performing arthroscopic-assisted VLP fixation. There were no differences in other postoperative radiographic outcomes, complications, or functional outcomes.

Conclusions The current literature suggests that arthroscopic-assisted VLP is a useful adjunct to intra-articular reduction and treatment of associated soft tissue injuries in distal radius fractures. Considerations should include operative time, costs, and the additional training required. Further studies are needed to assess functional outcomes. *(J Hand Surg Am. 2022;■(■):■−■. Copyright © 2021 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic II.

Key words Arthroscopic-assisted, arthroscopy, distal radius fracture, meta-analysis, volar plate.

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Distal radius fractures (DRFs) are among the most common fractures in the world, and treatment varies from nonsurgical treatment with casting to surgical fixation based on fracture characteristics and the patient's profile, expectations, and demands.[1,2] Rates of both operative intervention and the use of volar locking plate (VLP) technology have substantially increased.[3,4] The literature shows that VLP offers better reduction of intra-articular fragments and outcomes compared to external fixation combined with percutaneous pins.[5–7] Indeed, the use of VLP as a proportion of operative intervention for DRF increased from 42% in 1999 to 81% in 2007.[8]

Clinical outcomes are dependent on restoration of bony alignment, as well as treatment of associated soft tissue injuries, such as to the scapholunate, lunotriquetral, and triangular fibrocartilage complexes.[9,10] An intra-articular gap or stepoff greater than 1−2 mm is a prognostic factor for posttraumatic osteoarthritis.[11]

Wrist arthroscopy in DRF has been evaluated as an adjunct to surgery, with multiple techniques and surgical strategies published.[8,12–24] The theoretical advantages of arthroscopic-assisted distal radius fixation (AADRF) include the ability to debride and evacuate an intra-articular fracture hematoma; assess and adjust an intra-articular reduction; identify and manage concomitant soft tissue injuries; and prevent inadvertent intra-articular screw penetration. Disadvantages are believed to include an increased operative time and requirements for greater expertise, more equipment, and further training, as well as the related costs of these requirements.

Thus, the objective of this study was to compare arthroscopic-assisted to fluoroscopic-assisted VLP fixation of DRF through a systematic review and meta-analysis of the published literature. We aimed to compare fracture reduction, as well as reported procedural and functional outcomes.

MATERIALS AND METHODS

Protocol

A systematic search and retrieval of publications was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[25]

Search strategy

Four databases (Cochrane, EMBASE, Medline, and Scopus) were searched from inception to May 2020. A systematic search was conducted for studies via a combined text and MeSH or Emtree search, using key terms including "arthroscopy," "wrist arthroscopy," "wrist injuries," "fracture," and "distal radius." No limits were applied for publication type, language, or year of publication. A manual search was also performed through the references of included studies.

Two authors (Z.S. and B.S.) independently screened the titles and abstracts of all articles for eligibility, using the inclusion and exclusion criteria. After screening, full texts were retrieved. Disagreement was addressed by discussion until consensus was reached.

Study selection and eligibility criteria

Original studies were included if (1) arthroscopic-assisted VLP was performed on a DRF; (2) comparison was made with fluoroscopic-assisted distal radius fixation (FADRF); and (3) radiographic, procedural, or functional outcome data were reported.

Studies were excluded if the DRF were part of a multi-trauma, were open injuries, or had concomitant fractures. Studies were also excluded if they did not present relevant outcome data, had either no comparison or comparison to techniques other than FADRF, or were technique guides, cadaveric studies, systematic reviews, or opinion pieces.

Outcome measures

The primary outcome was postoperative radiographic reduction and alignment. These were grouped into 5 categories: (1) postoperative gap (mm); (2) postoperative stepoff (mm); (3) radial inclination (degrees); (4) volar tilt (degrees); and (5) ulnar variance (mm).

The secondary outcomes were procedural and functional outcomes. Procedural outcomes were grouped into 3 categories: (1) operative time (minutes); (2) identification of additional soft tissue injuries (scapholunate, lunotriquetral, or triangular fibrocartilage complexes injury); or (3) complications (all reported postoperative adverse outcomes).

Functional outcomes included: range of motion in degrees, visual analog scale for pain score, Mayo clinic score, Disabilities of the Arm Shoulder and Hand (DASH) score, Patient-Rated Wrist Evaluation score, and grip strength (kg). As the DASH and *Quick*DASH scores address the same questions and both range from 0−100, their results were reported together.

Risk of bias

The Cochrane Risk of Bias Tool for Randomized Controlled Trials was used for randomized controlled

TABLE 1. Study Characteristics

Author	Year	Study Type	Pt no (n) Fluoroscopic	Pt no (n) Arthroscopic	Fracture Type	Sex (%F)	Mean Age (Years)	Arthroscopic Technique	Radiographic Assessment (Assessment Time)	Risk of Bias
Burnier et al, 2018[37]	2018	Prospective	20	20	AO Type C	52.5	44	Traction: vertical Dry/wet: dry Scope 2.7 mm 30° Portals: 3/4, 6R, MCR, MCU	CT (NR)	Low
Christiaens et al, 2017[34]	2017	Retrospective	20	20	AO Type C	52.5	45.5	Traction: yes, NS Dry/wet: NS Scope: NS Portals: NS	CT (3 months)	Low
Fang and Wang, 2019[35]	2019	Retrospective	39	11	AO Type C	50	55.4	Traction: vertical Dry/wet: NS Scope: NS Portals: 3/4, 6R	X-ray (Day 1)	Low
Saab et al, 2019[36]	2019	Retrospective	23	18	AO Type C	43.9	44.6	Traction: vertical Dry/wet: dry Scope: 2.7 mm 30° Portals: 3/4, 6R	CT (3 months)	Low
Selles et al, 2020[28]	2020	RCT	25	25	AO Type C	66	59	Traction: vertical Wet/dry: NS Scope: NS Portals: 3/4, 6R, MCR, MCU	N/A*	Low
Yamazaki et al, 2015[29]	2015	RCT	34	36	AO Type C	77.1	63.5	Traction: NS Dry/Wet: NS Scope: 2.7 mm 30° Portals: 3/4, 4/5, and 6R and/or 6U	CT (3 months)	Low

CT, computed tomography; N/A, not assessed; NR, not reported; NS, not specified; MCR/MCU, midcarpal radial/ulna; 6R/U, 6 radial/ulna.

*Arthroscopy for debridement of a hematoma only, with no adjustment to reduction or treatment of soft tissue injuries (triangular fibrocartilage complexes, scapholunate injury, or lunotriquetral injury).

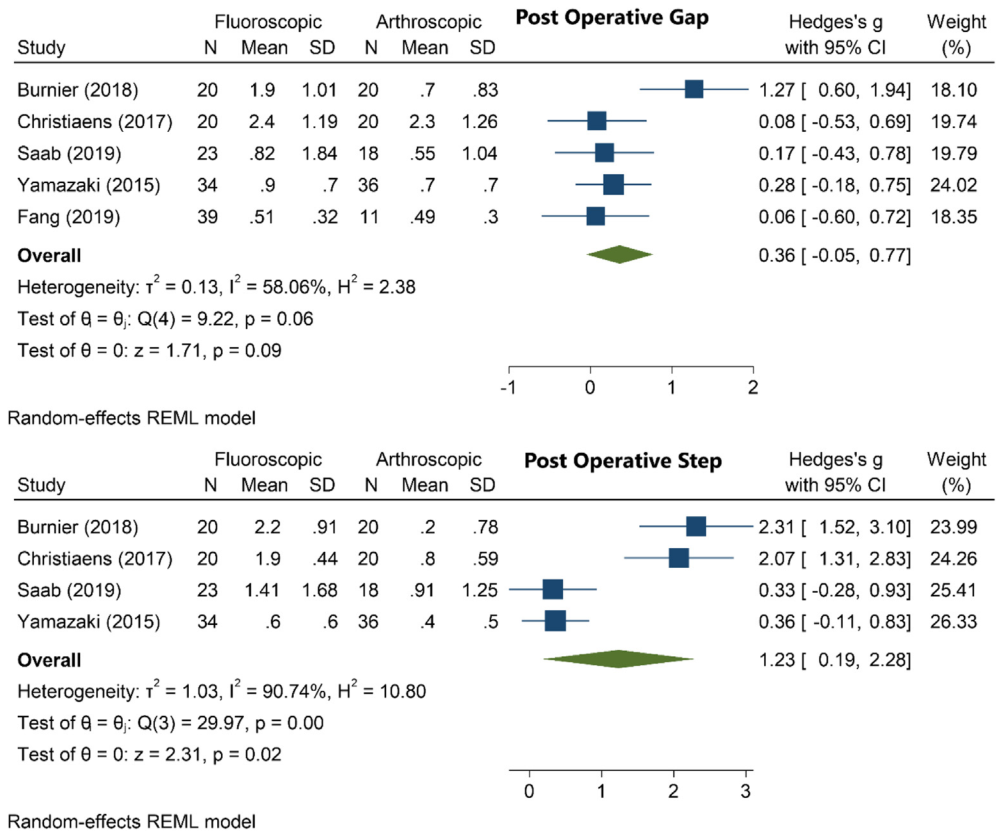

FIGURE 1: Forest plot for postoperative gap and stepoff. In the x-axis, Hedges' g is a measure of the effect size between groups after the intervention using a pooled SD. A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. Theta represents the average Hedges' g across all studies. CI, confidence interval.

trials (RCTs), and Risk of Bias in Non-randomized Studies of Intervention was used for nonrandomized studies to assess the individual risks of bias of included studies (Table 1).[26,27] All studies were categorized as having a low risk for selection bias. Inherent to the nature of arthroscopy, the performance bias was rated as having a high risk because blinding was not possible.

Statistical analysis

Continuous data were expressed as means and SDs, and categorical variables were expressed as frequencies. Where there were missing data, corresponding authors were contacted, and original data were made available. This included ranges of motion and grip strengths from 2 studies.[28,29] A random-effects meta-analysis model was used, which incorporates both between-study variation and within-study variation, to obtain pooled estimates for each outcome.[30]

The between-group Hedges' g effect size was calculated for each specific outcome with 95% confidence intervals. Hedges' g is a measure of the effect size between groups after an intervention using a pooled SD.[31] A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. *Theta* represents the average Hedges' g across all studies. The test of $theta = 0$ was used to provide a statistical test as to whether the effect size is statistically significant. In this instance, a P value $< .05$ will indicate the effect size is statistically different from 0.

Heterogeneity and publication bias

Tests of heterogeneity were conducted with the Q statistic, which is distributed as a chi-square variate. The extent of between-study heterogeneity was assessed with the I^2 statistic.[32] A rough guide to I^2 interpretation is as follows: a result of 0% to 40% might not be important; a result of 30% to 60% may represent moderate heterogeneity; a result of 50% to 90% may represent substantial heterogeneity; and a result of 75% to 100% represents considerable heterogeneity.

Publication bias was investigated with an Egger test, where a P value $< .05$ indicates possible publication bias, and was graphically demonstrated using funnel plots.[33] These were assessed if the meta-analysis gave a significant result.[33]

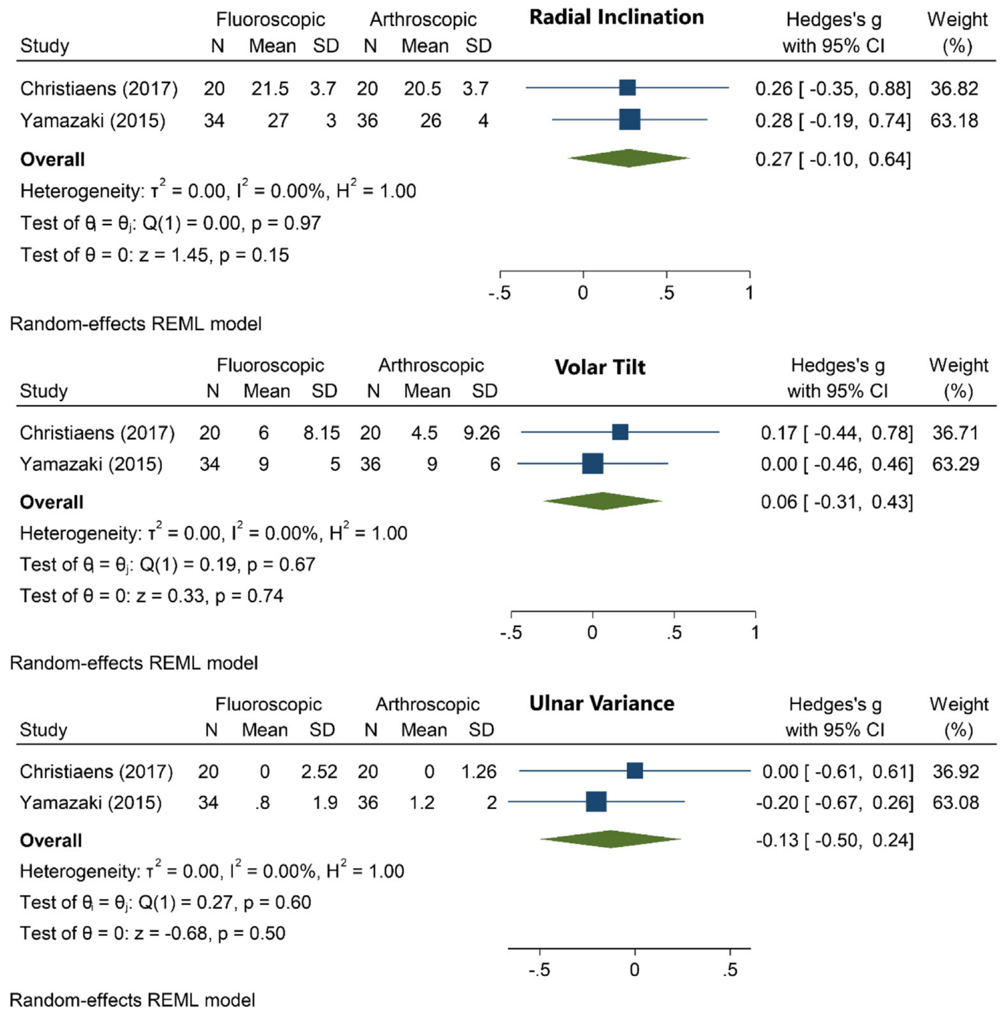

FIGURE 2: Forest plot for radial inclination, volar tilt, and ulnar variance. In the x-axis, Hedges' g is a measure of the effect size between groups after the intervention using a pooled SD. A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. Theta represents the average Hedges' g across all studies. CI, confidence interval.

RESULTS

The systematic literature search identified 430 articles. A total of 84 full-text articles were reviewed after screening the title and abstract, and 6 studies met the inclusion criteria.

Study characteristics

A total of 6 studies involving 280 participants were included (Table 1). A total of 161 participants (57.5%) underwent FADRF, while 119 (42.5%) underwent AADRF. The pooled mean cohort age was 52 years old, and 160 (57%) participants were women. Two studies were RCTs; 3 were retrospective case-control studies; and the last was a prospective case-control study.[28,29,34–37] Other information on patient and fracture characteristics was poorly described. The time to surgery, postoperative instructions, and surgical technique, including the plate manufacturer, were variable across the studies (Table 1). There was a variety of implants used, and 2 studies did not report the choice of plate.[28,35]

Wrist arthroscopy was used to assist in reduction in all studies except 1.[28] In this study, wrist arthroscopy was used for debridement of a hematoma and debris only, with no change to the articular reduction and all soft tissue injuries left untreated.

A postoperative reduction was assessed by computed tomography in 4 studies and plain radiographs in 1 study (Table 1).[29,34–37] One study did not assess reductions on postoperative radiographs because no intraoperative arthroscopic-assisted adjustments were performed.[28]

Postoperative radiographic reduction and alignment

Five studies reported on the postoperative gap and 4 studies reported on the postoperative stepoff (Fig. 1).[29,34–37] A meta-analysis of the pooled effect

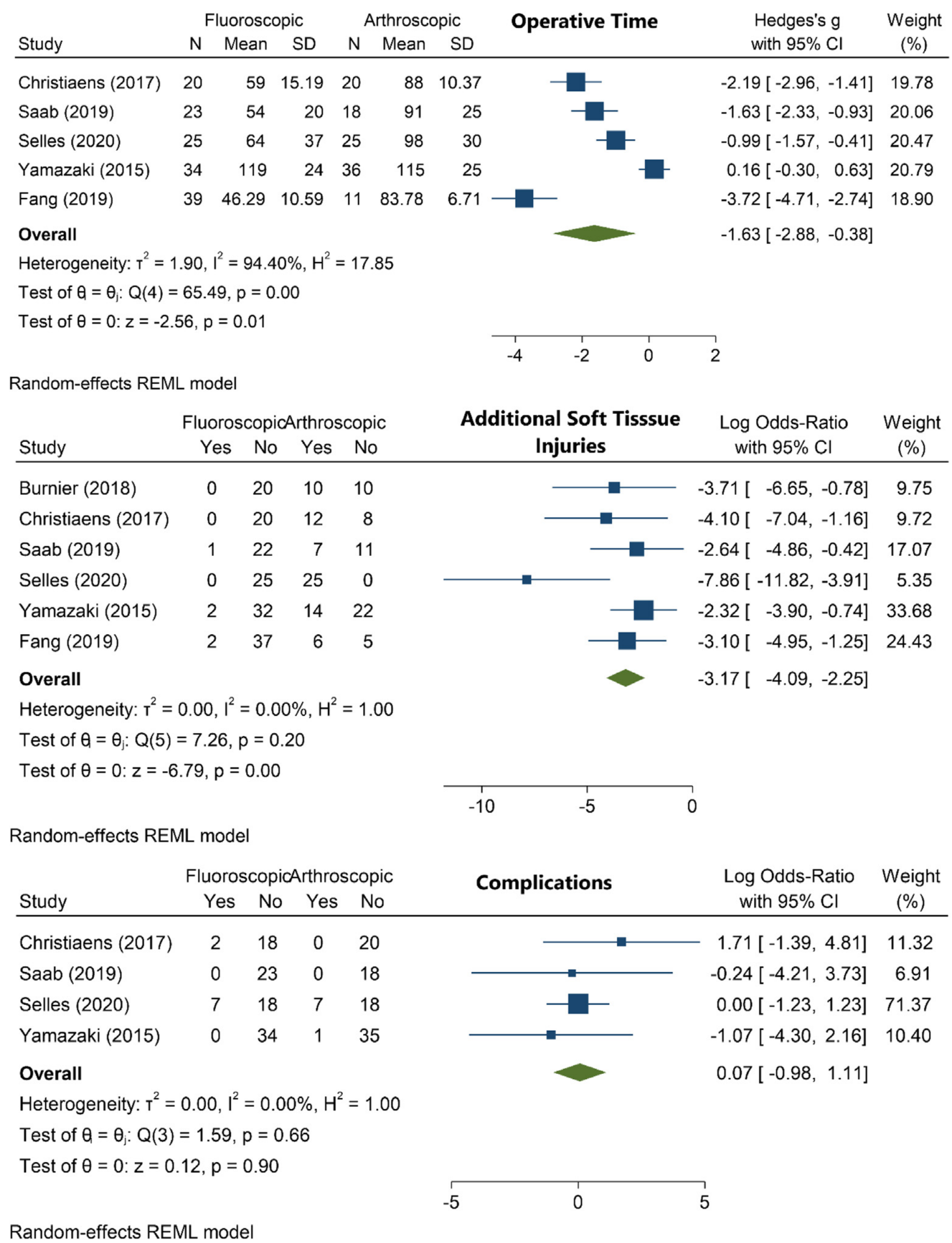

FIGURE 3: Forest plot for operative time, additional soft tissue injuries, and complications. In the x-axis, Hedges' g is a measure of the effect size between groups after the intervention using a pooled SD. A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. Theta represents the average Hedges' g across all studies. CI, confidence interval.

size for postoperative stepoff was statistically significant (Hedges' g, 1.23; $P < .05$) in favor of the arthroscopic group, but not when considering the postoperative gap (Hedges' g, 0.36; $P > .05$).

Tests for hetrogeneity indicated there may be moderate to considerable heterogeneity amongst the studies ($I^2 = 58.1\%$ and 90.7%, respectively). For the postoperative stepoff, the Egger test for publication bias was statistically significant ($P < .05$) and the funnel plot is asymmetrical (Fig. E1, available online on the *Journal*'s website at www.jhandsurg.org), suggesting possible publication bias. Due to our small sample size, this result should be considered only a qualitative difference of unknown magnitude.

Two studies reported on the postoperative radial inclination, volar tilt, and ulnar variance (Fig. 2).[29,34] Meta-analyses of the pooled effect sizes for each outcome were not statistically significant (radial inclination [Hedges' g, 0.27; $P > .05$], volar tilt [Hedges' g, 0.06; $P > .05$], ulnar variance [Hedges' g, −0.13; $P > .05$]).

TABLE 2. Summary of Functional Outcome Reporting Used in Analysis (Months)

STUDY	BURNIER ET AL, 2018[37]	CHRISTIAENS ET AL, 2017[34]	FANG AND WANG, 2019[35]	SAAB ET AL, 2019[36]	SELLES ET AL, 2020[28]	YAMAZAKI ET AL, 2015[29]
VAS	NR	NR	NR	12	3	NR
ROM	NR	NR	3	12	3	11
Mayo CLINIC SCORE	NR	NR	3	12	NR	NR
DASH OR *QUICKDASH*	NR	NR	NR	12	12	11
PRWE	NR	NR	3	NR	12	NR
GRIP STRENGTH	NR	NR	NR	NR	3	3

NR, not reported; PRWE, Patient-Rated Wrist Evaluation; ROM, range of motion; VAS, Visual Analog Scale.

Procedural outcomes

Five studies reported on the operative duration; 6 studies reported on additional soft tissue injuries; and 4 studies reported on complications (Figure 3).[28,29,34–37]

Five studies reported on treatment of additional soft tissue injuries that accounted for 29 of 49 identified.[29,34–37] Selles et al[28] used arthroscopy for debridement of hematoma only with no treatment of soft tissue injuries.

Patients who underwent AADRF had a significantly greater operative duration (Hedges' g, −1.63; $P < .05$); similarly, there was a higher incidence of identification of additional soft tissue injuries in this group (log odds ratio, −3.17; $P < .05$). The complications were not statistically significant (log odds ratio, 0.07; $P > .05$).

Functional outcomes

There was large variability in time frames of functional outcome reporting among the studies. Where possible, functional outcome data were extracted at 3 months after surgery. Where these data were not available, outcomes were extracted from the final time frame reported (Table 2).

Four studies reported on range of motion (Fig. 4).[28,29,35,36] A meta-analysis of the pooled effect size was statistically significant for extension (Hedges' g, −0.71; $P < .05$), in favor of AADRF. There were no significant differences in flexion, pronation, and supination between groups.

In terms of other functional outcomes, 2 studies reported on each of visual analog scale pain scores, Mayo clinic scores, Patient-Rated Wrist Evaluation scores, and grip strength.[28,29,35,36] Three studies reported on DASH or *Quick*DASH scores.[28,29,36] A meta-analysis of the pooled effect size was not statistically significant for any of these outcome measures ($P > .05$) (Fig. 5).

DISCUSSION

This meta-analysis compared outcomes between arthroscopy-assisted and fluoroscopy-alone fixation of DRFs. Six studies met the criteria for inclusion, yielding a cohort of 280 patients. Arthroscopic-assisted DRF was associated with a significant improvement in intra-articular reduction, as measured by postoperative stepoff. There were no significant differences in other postoperative radiographic reduction measures. Of the secondary outcomes, AADRF was associated with a statistically significant increase in identified soft tissue injuries and wrist extension; this was counteracted by longer operative

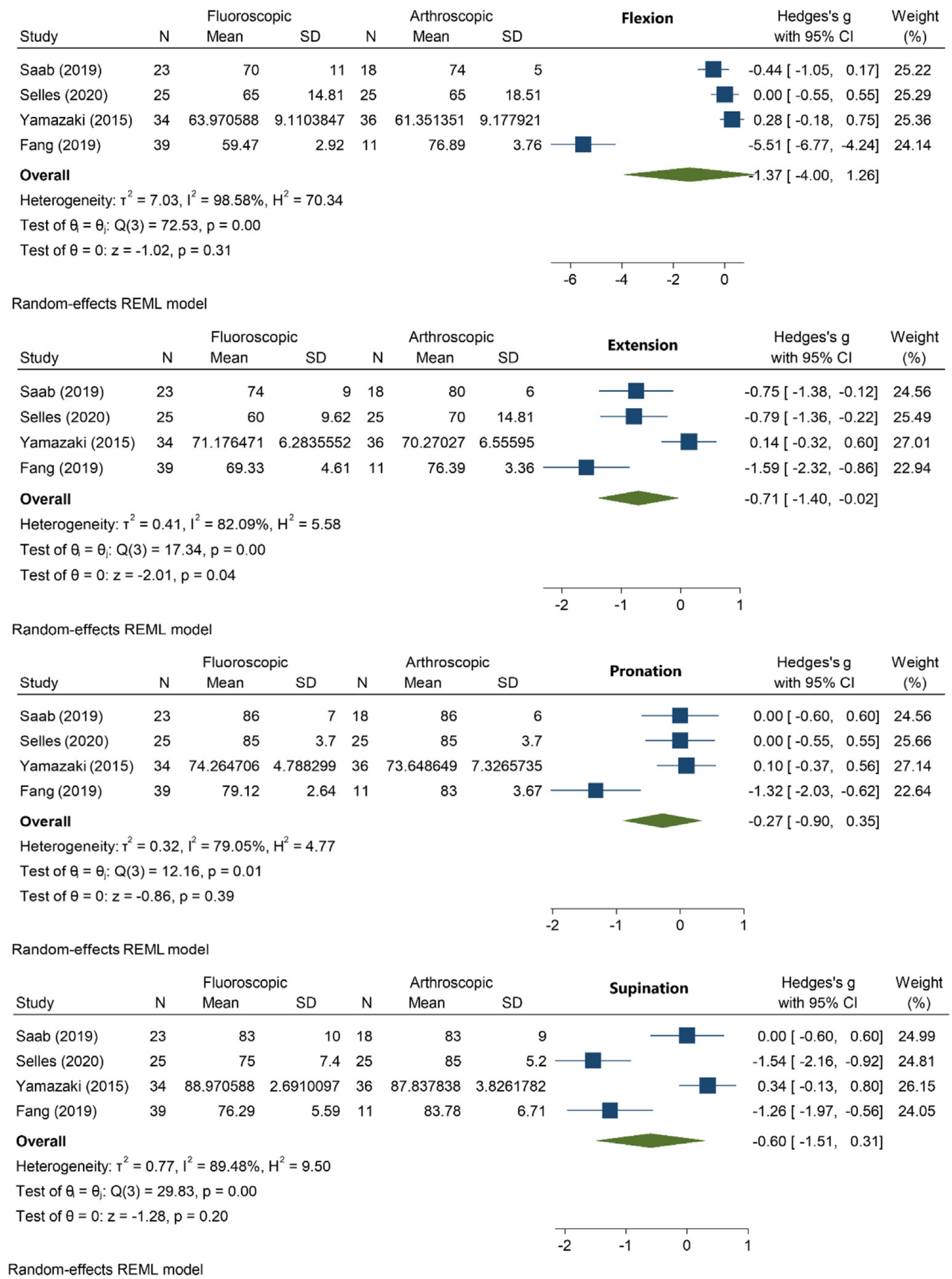

FIGURE 4: Forest plot for range of motion: flexion, extension, pronation, and supination. In the x-axis, Hedges' g is a measure of the effect size between groups after the intervention using a pooled SD. A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. Theta represents the average Hedges' g across all studies. CI, confidence interval.

times. There were no statistically significant differences in all other procedural and functional outcomes.

A residual intra-articular gap or stepoff between 1 and 2 mm is a prognostic factor for posttraumatic osteoarthritis.[9,38] A combined incongruity (gap plus step) is also an important marker for outcomes.[39] Therefore, efforts should be made to improve reduction where possible.

Fluoroscopy overestimates intra-articular reduction when compared to arthroscopy.[38,40] Authors have described techniques and experiences using arthroscopy to assist intra-articular reduction in DRF with VLP.[14–24] Our findings align with these studies in that reduction is better appreciated with arthroscopy, particularly for an intra-articular stepoff, and they are in line with those of a recent systematic review, where most studies reported improved

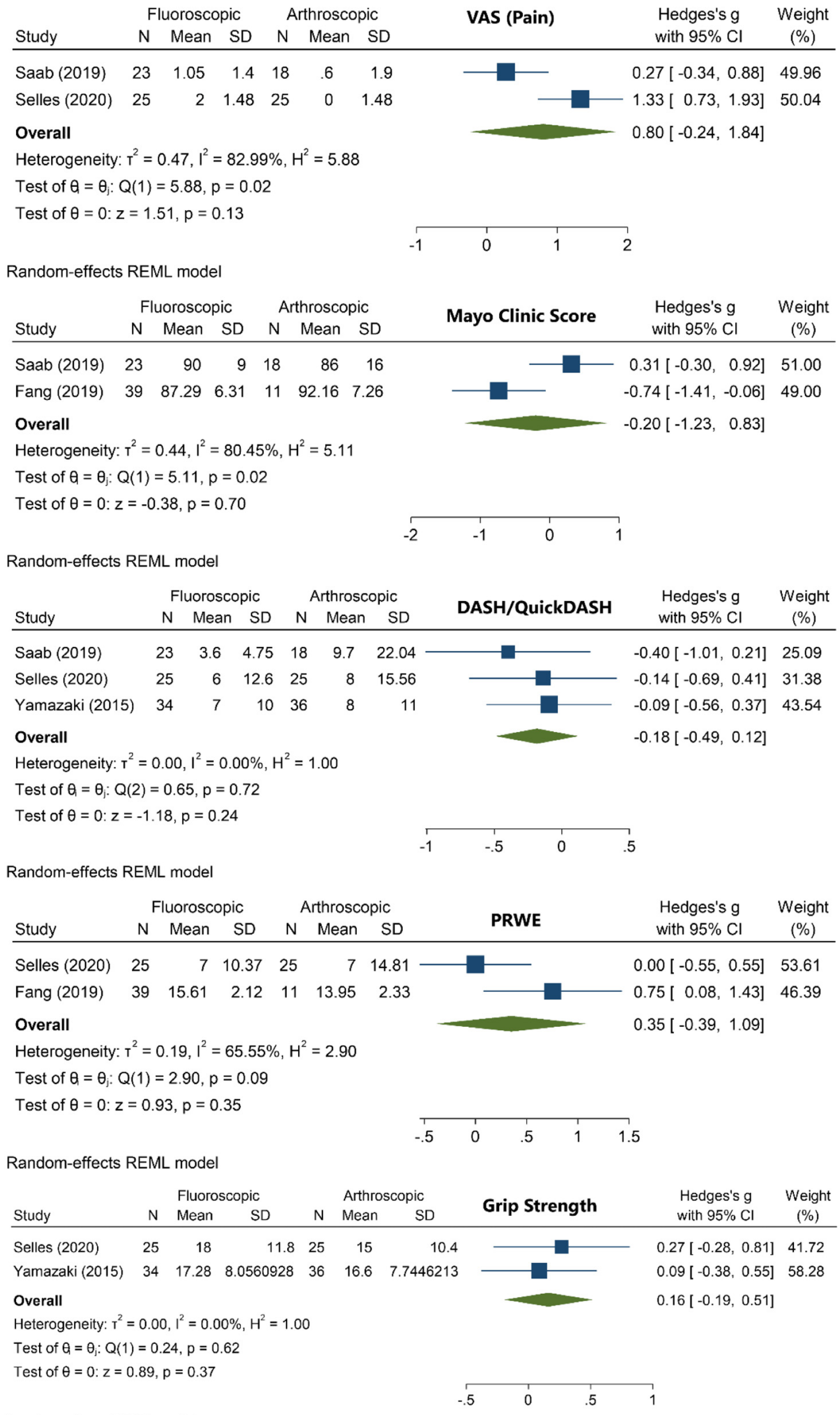

FIGURE 5: Forest plot for functional outcomes: VAS (pain), Mayo clinic score, DASH or *Quick*DASH, PRWE, and grip strength. In the x-axis, Hedges' g is a measure of the effect size between groups after the intervention using a pooled SD. A Hedges' g of 0 indicates there is no difference between the groups and a Hedges' g of 1 indicates the 2 groups differ by 1 SD. Theta represents the average Hedges' g across all studies. CI, confidence interval; PRWE, Patient-Rated Wrist Evaluation; VAS, Visual Analog Scale.

reduction with the use of arthroscopy.[13] Although no difference was found in postoperative gap, we believe the reduction in postoperative stepoff is important in reducing the risk of posttraumatic osteoarthritis. Additionally, arthroscopy can be utilized to assess screw protrusion, which can be adjusted accordingly.[24]

Extra-articular reduction also influences outcomes.[41] A meta-analysis to evaluate extra-articular alignment (including radial inclination, volar tilt, and ulnar variance) found no difference between the 2 groups; however, these parameters were only reported in 2 studies.[29,34] Thus, there is a paucity in the literature assessing these measures in AADRF, although these early findings suggest that arthroscopy does not have a negative effect on extra-articular reduction, as is expected.

Despite heterogeneity in surgical factors, including technique, implant, and surgical experience, this review found no difference in complications. Arthroscopy confers a low inherent risk of increased complications, although the associated learning curve and setup will result in a longer operative duration. As both the surgeon and team members become familiar with the procedure, this additional time expenditure is expected to be minimized.

This study found that arthroscopy allowed increased identification of soft tissue injuries, similar to previous literature reporting rates of associated pathology between 40% to 80%.[8,13] This highlights the large proportion of injuries that would go undiagnosed without arthroscopy, with the possibility of progression from partial to complete injuries with early motion when VLPs are used.[24] Furthermore, some studies show that inadequate treatment can impair outcomes.[42–45] A retrospective study, however, found that there was no difference in patient-reported outcomes in patients thought to have a scapholunate injury associated with intra-articular DRFs.[46]

This meta-analysis found a statistically significant increase in postoperative wrist extension in AADRF, although the clinical importance of this finding was not established. No difference was found in other functional outcome measures. Interpretation of these results was limited by small numbers and variability in the time frames of outcome reporting. Although AADRF may improve intra-articular reduction, some studies have found short- and long-term functional outcomes do not correlate with the residual stepoff and gap, nor the development of posttraumatic arthritis.[47,48] However, these studies showed satisfactory extra-articular alignment, and few had major articular displacement.[49]

This meta-analysis compared outcomes between AADRF and FADRF. It has limitations: only 2 of the included studies were RCTs, highlighting the difficulty of performing these studies in a clinical setting; most studies were small in size, with the largest involving 70 patients; statistically significant heterogeneity was demonstrated in the key outcomes assessed; there was variability in patient (eg, age) and surgical (eg, technique and internal fixation implants) factors that were not assessed; and asymmetric funnel plots indicate a risk of selection bias. However, we interpreted that AADRF is a useful adjunct, allowing improvements in intra-articular reduction and treatment of associated soft tissue injuries without compromising extra-articular alignment or increasing complications. Considerations should include the increased operative time and cost, as well as the associated learning curve and additional training required. Wrist extension and reduction of intra-articular stepoff may be improved, although long-term, large, multicenter RCTs are needed to further assess whether that is associated with clinically meaningful differences in functional outcomes.

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Appendix

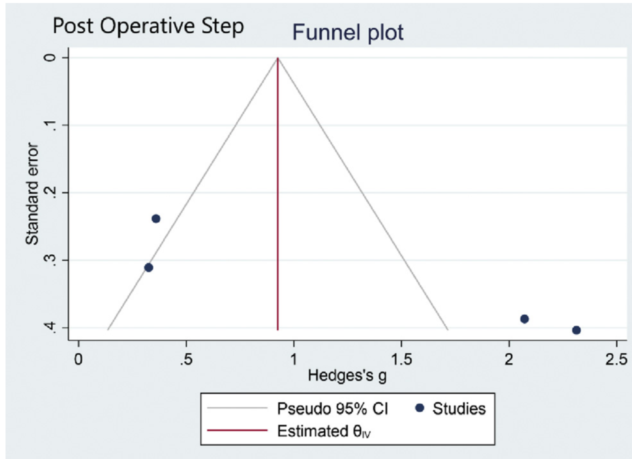

FIGURE S1: Funnel plot for postoperative step. CI. confidence interval