Original Research

Management of Acute Distal Radioulnar Joint Instability Following a Distal Radius Fracture: A Systematic Review and Meta-Analysis

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Purpose: We sought to review the clinical outcomes of conservative and operative treatment options for acute distal radioulnar joint (DRUJ) instability associated with distal radius fractures in adult patients.

Methods: A systematic search of PubMed, MEDLINE, and EMBASE for articles published between 1990 and 2020 involving DRUJ instability associated with distal radius fractures was performed. The primary outcomes analyzed included clinical grip strength; range of motion; the disability of the arm, shoulder and hand (DASH) score; and the modified Mayo wrist score (MMWS).

Results: Of the 531 articles identified in the literature search, 8 met our defined criteria and were included in the final analysis. The cumulative sample size was 258 patients at a mean follow-up of 11.1 months (range, 3–16.9 months). Treatment groups included cast immobilization in supination, K-wire stabilization, and triangular fibrocartilage complex (TFCC) repair. Statistical analysis revealed no difference across groups in active flexion-extension or DASH scores. A significant decrease in grip strength was found in patients who underwent TFCC repair compared with that in those who underwent both cast immobilization ($P = .04$) and K-wire stabilization ($P = .02$). Furthermore, we found a significant decrease in active pronation-supination between patients who underwent TFCC repair and those who underwent cast immobilization ($P = .03$). Patients who underwent TFCC repair were also found to exhibit decreased MMWS as compared with those who underwent K-wire stabilization ($P = .05$). Overall, persistent DRUJ instability was only found in 4 patients (1.5%), without a significant difference between treatment groups.

Conclusions: This study suggests functional advantages of certain treatment modalities over others, with the range of motion being highest in patients who underwent cast immobilization and grip strength being highest in patients who underwent K-wire stabilization. However, the mean DASH scores showed no difference across all groups, calling into question the clinical need to pursue operative treatment via K-wire stabilization or TFCC repair over conservative treatment via cast immobilization. This study will hopefully serve as a foundation for future prospective studies to help improve and standardize treatment algorithms in patients with DRUJ instability and distal radius fractures.

Type of study/level of evidence: Therapeutic II.

Distal radius fractures (DRF) are the most common fractures of the upper extremities, with an incidence of approximately 640,000 in the United States per year.[1] Meanwhile, the incidence of concomitant distal radioulnar joint (DRUJ) instability varies widely.[2–4] Although the optimal treatment method of associated acute DRUJ instability in the setting of DRF is controversial, many studies suggest that DRUJ instability is a poor prognostic factor, often resulting in chronic pain, decreased range of motion, and decreased grip strength if undiagnosed or untreated.[5–8]

The DRUJ is an anatomically complex structure with little inherent bony stability. This is due to a mismatch of the radius of curvature between the relatively larger sigmoid notch and ulnar head as well as the shallow nature of the articulation. This bony architecture enables a full 160° arc of pronosupination but comes at the cost of instability to volar and dorsal translation.[9] Previous biomechanical studies have shown that the dorsal and volar radioulnar ligaments (RUL) that comprise the triangular fibrocartilage complex (TFCC) are the main restraint to DRUJ translation, along with contributions from the interosseous membrane (IOM) and the dorsal capsular ligaments (DCL).[9–13] Therefore, it is not surprising that DRFs with associated TFCC injuries involving the RUL or ulnar styloid fractures that disrupt the foveal attachment of the deep RUL insertion have been associated with a higher incidence of DRUJ instability.[6,14–19] However, the effect of TFCC repair on restoring DRUJ stability is controversial. Previous studies have shown that associated ulnar styloid fracture non-union after DRF fixation does not lead to long-term DRUJ instability.[20–23] In addition, while studies have shown good preliminary results with arthroscopic TFCC repair, there remains no high quality evidence indicating that repair is necessary, provided the DRF is anatomically reduced and stabilized.[18,24,25]

These findings have led many authors to argue that, in the context of persistent DRUJ instability following anatomic reduction and fixation of the DRF, the added surgical time and potential risk of morbidity of TFCC repair may not be justified,[11,26] particularly in cases with intact support from other structures such as IOM and DCL.[10,12,27] Therefore, other treatment options, such as cast immobilization or K-wire stabilization of the DRUJ, should be considered.[11,28–31]

Given the lack of consensus regarding a standardized treatment algorithm and reference standard for the diagnosis of DRUJ instability, the purpose of this systematic review is to comprehensively investigate and compare outcomes of conservative and surgical treatment of acute DRUJ instability associated with a DRF fracture. Results from this analysis will hopefully highlight functional differences across treatment groups in order to better inform optimal care for this challenging patient population. We hypothesized that conservative treatment would be non-inferior to more invasive options.

Materials and Methods

Protocol

The study protocol was registered with PROSPERO, an international prospective register of systematic reviews (CRD42020197386). This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[32] and the Figure depicts the study identification process. To identify relevant publications, we searched PubMed, MEDLINE, and EMBASE and included studies published between January 1990 and May 2020. The key words used in the search queries were "DRUJ," "instability," "repair," "fracture," "TFCC," "ulnar," "styloid," "radioulnar," and "reduction." Studies in which a part of the study population met the inclusion criteria were included if the results of the subpopulation were presented separately. References of included articles were reviewed to incorporate additional relevant studies. Articles not available in English and duplicates were removed. Review articles, case reports, and technical notes as well as studies that had repeated patients or included a subset of future articles were also excluded.

Studies were initially screened by the primary author based on title and abstract and then further eliminated with a full manuscript review. A study was included if it met all of the following criteria: (1) the study population included adult patients with DRF, (2) acute DRUJ instability was measured intraoperatively or immediately post-operatively, (3) the patient received treatment for the DRUJ instability, and (4) the distal radius fracture underwent anatomic reduction and internal fixation. Theoretically, larger associated ulnar styloid and ulnar styloid base fractures are thought to be inherently unstable secondary to their TFCC and ligamentous attachments.[33,34] As a result, patients with more extensive fracture patterns such as ulnar fractures involving more than the tip of the ulnar styloid or fractures with extensive comminution of the ulnar head were excluded.

Quality assessment

The level of evidence for each study was recorded following The Journal of Bone and Joint Surgery and the Oxford Centre for Evidence Based Medicine criteria and was graded by the primary author from levels 1 through 5.[35]

Data extraction

The primary outcomes analyzed were functional clinical measures. Clinical data extracted from the final studies were patient demographics, treatment interventions, length of follow-up, and clinical results, defined by grip strength, range of motion, DASH score,[36] MMWS,[37] and incidence of chronic DRUJ instability.

Data analysis

Upon final screening, data from articles were pooled for analyses distinct cohorts created based on treatment group. Final treatment groups included cast immobilization, K-wire stabilization and TFCC repair (arthroscopic and open). Of note, as the ulnar fovea is the attachment site for the deep radioulnar ligaments within the TFCC, we included fixation of ulnar styloid tip fractures into this treatment group. Patients who underwent fixation of more extensive ulnar fractures were omitted. In order to calculate averages for further analysis, cases were assigned frequency weights. Analysis of variance testing was conducted to analyze differences among treatment groups and Tukey testing was used to identify specific groups between which differences occurred. An alpha of 0.05 was set for determining significance for all clinical outcome measures.

Results

Study selection

A total of 531 articles were originally identified from the literature search as depicted in Figure 1. After excluding studies that did not meet the inclusion criteria, 8 studies were selected for inclusion in the systematic review (Table 1).
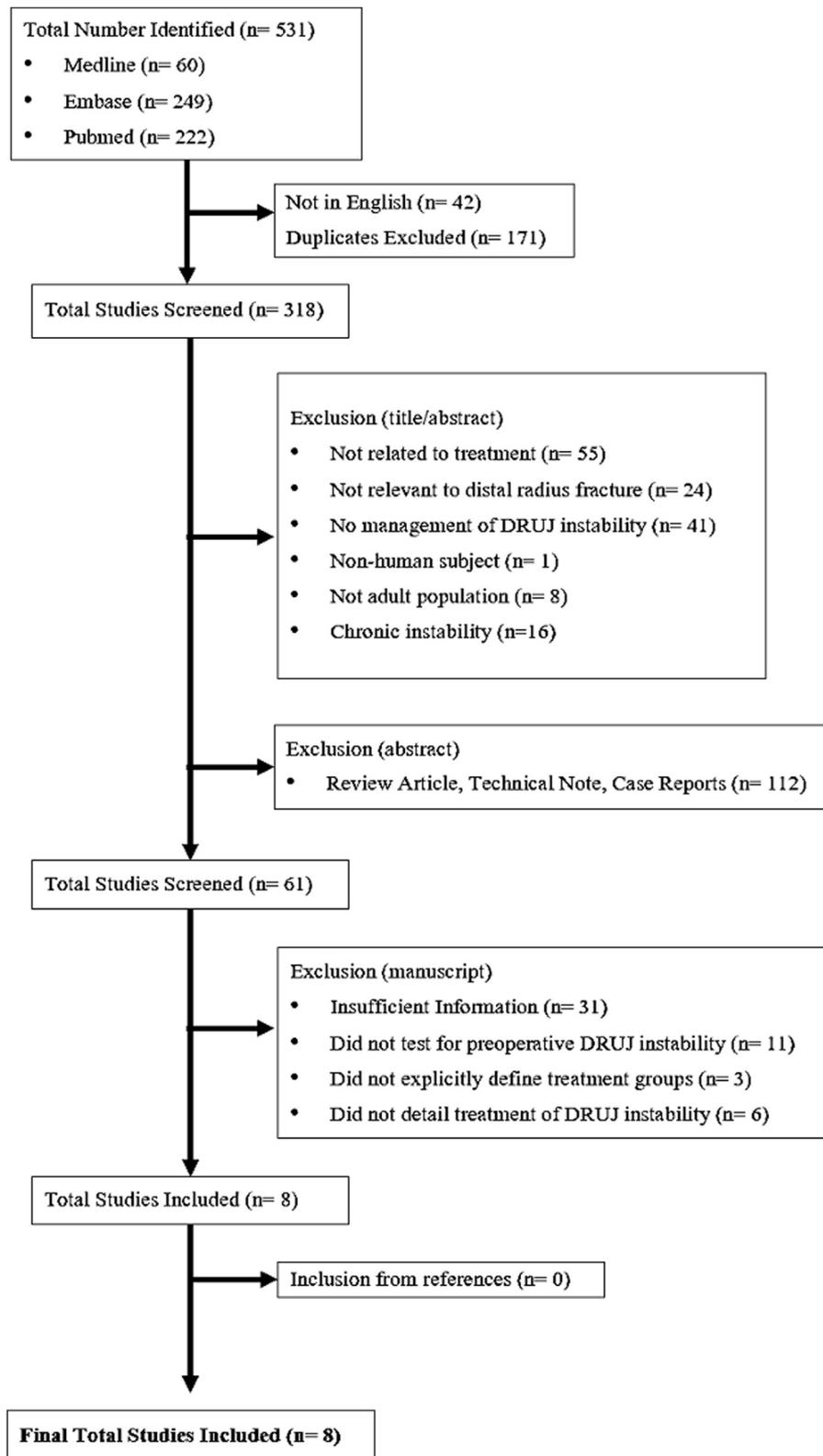
Figure 1. Flow diagram depicting the search strategy for inclusion of articles in the systematic review reported in accordance with the Preferred Reporting Systems for Systematic Reviews and Meta-Analysis statement.

Study demographics

Within the 8 included studies, a total of 258 wrists (258 patients) were analyzed with a weighted mean age of 53 years (range 18–89). The mean follow-up time was 11.1 months (range, 3–16.9 months). Of note, a significant number of patient fractures were classified as AO type C. Detailed demographics are displayed in Table 2.

Table 1
Details of Included Studies

Author/Year	Level of Evidence	Total DRUJ Repairs	Mean Age (years)	Female/Male (number)	Dominant/ Non- Dominant (number)	Mean Follow-up (months)	AO Type (type: number)	Treatment
Kaizeman/2011	IV	8	29.4	-	-	3	-	Long arm cast in supination (6 wks)
Lee/2016	III	130	58.3	82/48	-	16.9	-	Sugartong splint in midsupination (4ks) OR 1.6 mm K-wire fixation OR arthroscopic TFCC repair
Kim/2012	IV	19	45	10/9	-	12	-	Sugartong splint in 30 supination (4 wks)
Bajwa/2015	IV	15	53	-	-	12	A: 10 B: 5 C: 10	1.6mm K-wire fixation (1-2 dorsal, 1 radial)
Liu/2014	III	24	59.4	18/6	-	16	A: 8 B: 3 C: 14	1-2 K-wire fixation in neutral (6 wks)
Johandi/2017	IV	12	50.5	3/9	4/8	12	A: 3 B: 1 C: 8	Open TFCC repair
Garcia-Ruano/2014	IV	21	42	4/17	12/9	4.7	-	Arthroscopic TFCC repair
Gong/2015	IV	29	53	21/8	-	12	A: 12 B: 3 C: 14	Open TFCC suture

Clinical outcome measures

Final clinical outcomes evaluated are displayed in Table 3. Grip strength was significantly decreased in TFCC repair compared with both cast immobilization (18.7 kg vs 24.6 kg, $P = .04$) and K-wire stabilization (18.7 kg vs 25.3 kg, $P = .02$). No significant difference was found across treatment groups with regards to active range of motion in flexion-extension. However, TFCC repair was associated with a significant decrease in active pronation-supination when compared with cast immobilization (152. 2 vs 166.2, $P = .03$). In addition, TFCC repair was associated with decreased MMWS compared with those treated with K-wire stabilization (84.5 vs 89.6, $P = .05$). Despite having considerable power in the study, there was no statistical difference detected between groups when comparing DASH scores.

Across all patients included in the study, recurrent DRUJ instability post-operatively was rare (n = 4, 1.5%) and not associated with any specific treatment method. However, the method and frequency of screening were highly variable as no reference standard for diagnosing DRUJ instability in this setting currently exists.

Discussion

DRUJ stability is critical for proper force transmission between the forearm and wrist. Undiagnosed DRUJ instability can result in recurrent subluxation, dislocation, and/or pain.[3,38] Persistent, chronic instability at this joint is associated with many long-term complications, with specific links to ulnar sided arthritis, wrist pain, reduced grip strength, and motion limitation.[27,39–41] However, there is a paucity of data addressing the management of acute DRUJ instability following DRF treatment. Focusing on literature since 1990, we sought to systematically review all treatment modalities for DRF associated with secondary DRUJ instability.

Treatment groups identified included conservative management such as cast immobilization and surgical interventions, ranging from K-wire stabilization of the ulna to the radius to a more invasive TFCC repair. Patient outcomes were gauged *via* the MMWS, which favored K-wire stabilization over TFCC repair, as well as the DASH, which found no difference between the groups. As a physician-based scoring system, the MMWS is determined by the physician's assessment of pain, the active flexion/extension arc,

grip strength, and the ability to return to regular employment or activities.[42] Given the increased grip strength in K-wire patients compared with TFCC patients, it is reasonable to see the trend in MMWS score as well. Interestingly, the DASH is self-administered by patients and, thus, captures the patient's own perception of their recovery. While our results seem to indicate differences in functional outcomes, there seems to be minimal difference in patient satisfaction across all treatment groups. Thus, functional differences, while important, must be weighed when considering treatment options in the context of patient need and satisfaction.

Cast immobilization with the forearm in supination for 4 to 6 weeks is effective in providing the stability needed for the soft tissue stabilizers of the DRUJ to heal. However, concerns for joint stiffness and muscle atrophy from prolonged immobilization have limited its widespread use. Previous studies have indeed shown that cast immobilization for DRUJ instability does result in relatively worse short-term functional outcomes; however, long-term functional outcomes are comparable to patients who underwent operative treatment.[43] Our review builds upon this study and suggests that, despite initial immobilization, patients treated with cast immobilization have improved active range of motion at longer-term follow-up. This improvement is statistically significant when compared with surgical TFCC repair and may be attributable to the lack of scar formation related to open or percutaneous operative intervention.

K-wire stabilization of the DRUJ is an alternative strategy that effectively maintains DRUJ congruity by using the intact ulna as a strut to stabilize the soft tissue stabilizers of the DRUJ.[28,31] However, placement of the K-wire across the DRUJ can restrict prono-supination and lead to complications such as infection, hardware failure, pin-site irritation, and pain.[44,45] Moreover, K-wire stabilization requires a secondary pin removal procedure after 4 to 6 weeks to prevent stiffness and possible contracture.[21,45,46] In our study, K-wire fixation did lead to better grip strength and MMWS scores as compared with TFCC repair, but did not significantly improve wrist motion or DASH scores relative to cast immobilization. Therefore, the added time, cost, and potential morbidity relative to cast immobilization must be considered.

TFCC repair is another treatment alternative to cast immobilization and K-wire stabilization for DRUJ instability. Theoretically, the DRUJ is stabilized through direct re-attachment of the soft

Table 2
Reported Post-operative Outcomes by Treatment Group

Author/Year	Grip Strength (kg)	Flexion (°)	Extension (°)	Pronation (°)	Supination (°)	DASH	MMWS	DRUJ Instability at Follow-up (no. of patients)
Cast immobilization								
Kaizeman/2011	-	-	-	-	-	-	-	2
Lee/2016	24		105		158	14	85	0
Lee/2016*	23		122		164	17	89	0
Lee/2016**	24		122		166	16	83	0
Kim/2012	28	58	64	11	84	11	84	0
K-wire stabilization								
Bajwa/2015	-	-	-	-	-	3.5	-	0
Lee/2016	26		109		159	16	87	0
Lee/2016*	27		120		163	15	91	1
Lee/2016**	25		119		163	17	90	0
Liu 2014	23.8		103.5		152.3	-	-	0
TFCC repair								
Lee/2016	23		120		163	14	85	0
Johandi/2017	21.4	48	55.8	68.3	79.2	8.5	-	1
Garcia-Ruano/2014	-	-	-	-	-	8.1	84.2	0
Gong/2015	16	58	64	72	78	12	-	-

No star = patients without ulnar styloid process fractures; * = patients with ulnar styloid process tip fracture; and ** = patients with ulnar styloid process fracture.

Table 3
Comparison of Postoperative Outcomes by Treatment Group

Postoperative outcome	Treatment			*P* Value
	Cast Immobilization (n = 94)	K-wire Stabilization (n = 69)	TFCC Repair (n = 52)	
Grip strength (kg)[*]	24.6 ± 1.0	25.3 ± 0.8	18.7 ± 2.2	.01
Flexion-Extension (°)	120.0 ± 3.2	112.2 ± 4.3	117.4 ± 5.3	.44
Pronation-Supination (°)[†]	166.2 ± 2.7	158.6 ± 2.8	152.2 ± 4.0	.04
MMWS[‡]	84.9 ± 1.4	89.6 ± 1.2[§]	84.5 ± 0.4[§]	.04
DASH	15.0 ± 1.3	11.4 ± 3.8[§]	11.5 ± 1.5	.55

[*] Post hoc analysis shows significant difference between TFCC repair and other treatment options.
[†] Significant difference between cast immobilization and TFCC repair.
[‡] Post hoc analysis shows significant difference between TFCC repair and K-wire stabilization.
[§] Sample size differed in the analyses for MMWS comparing K-wire stabilization (n = 45) to TFCC repair (n = 32) and for DASH comparing K-wire stabilization (n = 60) to other treatment groups.

tissue stabilizers or fixation of their bony insertion to restore native anatomy. However, in our study TFCC repair failed to show any superior clinical benefit with regard to range of motion, grip strength, or functional outcome measures when compared with K-wire and cast immobilization. This is supported by previous studies that have shown that TFCC repair is not necessary to achieve a good long-term clinical outcome as long as there is stable anatomic DRF fixation.[24,47] This is also supported by studies that have shown residual DRUJ laxity after an untreated TFCC injury after DRF fixation is common (45%) and often painless (97% of patients).[48]

In addition, while this study did not directly address the impact of ulnar styloid fracture on DRUJ instability, the literature surrounding ulnar styloid fracture management is conflicting. Although some evidence may suggest that ulnar styloid base fractures may contribute to joint instability, a recent systematic review by Almedghio et al.[49] found no significant correlation between an ulnar styloid fracture and the functional and clinical outcomes of DRF treatment, irrespective of size or displacement of the ulnar styloid fragment. This is further supported by Yuan et al who conducted a meta-analysis on clinical outcomes in DRF patients with concomitant ulnar styloid fractures and demonstrated that there was no significant difference of outcomes between union and non-union of ulnar styloid fractures.[50]

Despite performing a comprehensive systematic review, there are several limitations to our study. First, the studies included had a relatively short follow-up time, ranging from 3 to 16.9 months. Second, most of the studies had a small sample size, owing to the low incidence of the injury complex and the difficulty in diagnosis, limiting the power of this study. Because of the limited number of available studies, we were unable to separate specific immobilization angles within cast immobilization, as immobilization ranged from mid supination to full supination and physicians often employed patient-specific angles within this range. We were also unable to control for hand dominance or stratify treatment groups by injury severity, although we note that the majority of included studies involved AO Class C fractures, indicating that these treatment options were considered in relatively high impact injuries. Lastly, although the objective and subjective outcome measures compared in this review are important components in determining a "successful" treatment, other patient-specific factors that were not included or measured may contribute to overall patient satisfaction. Moving forward, further studies are required to help determine the optimal treatment of DRUJ instability in this complex and controversial setting.

Based on our systematic review, clinical outcomes between the treatment groups do not support the use of more invasive TFCC repair to manage DRUJ instability associated with DRF. Moreover, across the groups, the incidence of persistent, symptomatic DRUJ instability at long-term follow-up was incredibly low regardless of post-DRF fixation treatment choice (1.5%). There may be tradeoffs between different techniques, with K-wire stabilization resulting in better grip strength and cast immobilization a better range of motion, but there is no indication that the time, effort, and expense of TFCC repair is necessary. However, larger controlled trials should be conducted to elucidate these differences and their implications on both functional outcomes and patient satisfaction.

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