Hand Stiffness Following Distal Radius Fractures
Who Gets It and Is It a Functional Problem?

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Abstract
Purpose: In order to identify predictors for hand stiffness following distal radius fractures and understand the consequences of this common clinical finding, we studied 260 patients. Our hypothesis was that we would find no predictors of post injury hand stiffness.

Methods: Baseline demographics and injury characteristics were obtained at distal radius fracture presentation. Treatment and healing was documented. Stiffness was defined as tip to palm distance greater than 1 cm for any one finger. Outcome parameters obtained at regular intervals included wrist and hand range of motion, radiographs, visual analog pain scales, and Disability of the Arm Shoulder and Hand (DASH) questionnaires.

Results: Forty-nine of 260 patients (19%) patients were considered to be “stiff” by our criteria. Grip strength was weaker for stiff patients as well. Patient demographics were similar in both groups with the “stiff” cohort having a greater mean age, $p = 0.05$. There was no significant difference in stiffness seen in operative cases versus nonoperative cases. Injury ulnar variance was 3.1 mm (SD = 3.5) in the “stiff” cohort and 1.8 (SD = 2.9) in the “non-stiff” cohort ($p = 0.02$). Functional disability as measured by the DASH differed ($p = 0.001$) between stiff and non-stiff patients for both 6 month and 1 year follow-up time points. Stiff patients were more likely than non-stiff patients to have lower grip strength at 12-month post fracture ($p = 0.001$).

Conclusion: Older patients who present with significant ulnar variance at injury are more likely to experience hand stiffness at some time during their recovery. The development of hand stiffness is associated with poorer functional outcome than those who do not develop stiffness.

Distal radius fractures (DRFs) have been reported to constitute up to one-sixth of all fractures with the incidence ranging from 10 per 10,000 to 120 per 10,000 person-years. These injuries pose a financial and social burden to society. The determinants of morbidity following distal radius fractures can provide insight into how to reduce the burden of distal radius fractures on the individual and society.

Many studies have evaluated outcomes following distal radius fractures. These studies have primarily used wrist range of motion, grip strength, and DASH scores as outcomes. What has not been examined is hand range of motion or more particularly the lack thereof or “hand stiffness” relative to distal radius fractures. Recovery of hand range of motion and manual dexterity following distal radius fractures may contribute to the clinical and functional outcome following DRFs, including grip strength, DASH scores, time out of work, and return to full-duty work. To our knowledge, there has not yet been a report of hand “stiffness” as it pertains to distal radius fractures.

The purpose of this study was to 1. identify sociodemographic and injury factors that predispose a patient to hand stiffness following distal radius fractures and 2. identify the association between hand stiffness and functional outcomes, including pain, DASH score, and grip strength.

Materials and Methods
This study was reviewed and approved by our institutional review board. Over a 5-year period, 606 patients
presenting to our institution with a distal radius fracture were identified. All fractures underwent closed reduction and application of a sugar tong splint. Informed consent was obtained and trained interviewers obtained baseline demographic data, injury information, and a baseline Disabilities of Arm, Shoulder and Hand functional scale (DASH). Exclusion criteria included incomplete data or follow-up at each time point and bilateral injury. Two-hundred-sixty patients who were treated with (N = 171) and without surgery (N = 89) met criteria and make up the cohort for this study. At presentation, all fractures were classified according to the system of the Orthopaedic Trauma Association (OTA).\[11\] This classification takes into account: fracture pattern, intra-articular involvement and comminution, and serves as an indicator of energy imparted to the fracture. Baseline data included socioeconomic factors, functional scores, and radiographic examination. Patients were treated operatively if they met the following criteria: intra-articular step off of greater than 2 mm, dorsal tilt of greater than zero, radial height less than 6 mm, and greater than 2 mm ulnar variance when compared to the opposite side. All patients were followed at 6 and 12 months postoperatively by their treating surgeon and a trained research associate. Patients who met the agreed upon criteria for closed treatment were discharged to follow-up in the outpatient setting within 1 week of presentation and re-examined clinically and radiographically to assess maintenance of the reduction. These criteria included less than 10° residual dorsal angulation (from neutral), less than 2 mm difference in ulnar variance compared to the contralateral side, 1 mm or less articular step off, no dorsal or volar subluxation of the DRUJ on the true lateral radiograph, and no widening of the DRUJ on the PA. If the reduction was maintained, patients were followed weekly for 3 weeks with x-rays to assess the maintenance of reduction. Measurement of all parameters was recorded. Surgery was indicated for those with an open fracture or those with an inherently unstable fracture pattern, which was generally defined as those with three of the following: initial dorsal angulation greater than 20°, initial shortening greater than 5 mm, greater than 50% dorsal comminution, intra-articular fracture, age greater than 60, and an associated ulna fracture. Surgery was also indicated for shear fractures or fracture-dislocation of the wrist.\[12-14\]

In patients who lost reduction and were considered to have met the radiographic criteria for surgery, a discussion of options was held between surgeon and patient. A decision for the best care of the patient was arrived at by mutual consent. Patients who did not undergo surgery were treated to completion with casting. Patients who required surgery were treated with either a volar locked plate or bridging external fixation with supplemental K-wire fixation (usually 2 to 3). The wrists treated with external fixation underwent closed reduction with application of two 3.0 or 3.3 mm pins in the base of the second metacarpal and two pins in the distal third of the radius. All pins were placed in an open manner.\[15-17\] The external fixator was used to distract and reduce the fracture via ligamentotaxis by flexion and ulnar deviation. Volar tilt was restored with the use of a Kapandji style K-wire, and then supplemental K wires were placed from the radial styloid and dorsal-ulnar corner to maintain the reduction. Once an acceptable reduction was obtained, the distraction was taken off the external fixator and the wrist placed in a neutral position. At this time, the fingers were passively flexed into a full fist position to ensure that there was no excessive distraction of the carpus and that the K-wires had not transfixed the extensor tendons. Intra-operative fluoroscopy was also used to judge and prevent over distraction of the carpus. The external fixation was kept on for 6 weeks, and the K wires and external fixation were removed in a staged fashion. The patients treated with a plate all underwent an extended FCR approach. All fractures were reduced open and stabilized with a locked pre-contoured volar plate (Hand Innovations, Miami FL, or Stryker, Mahwah, NJ).\[12-14\]

A validated outcome questionnaire was administered at each study visit: the Disabilities of the Arm Shoulder and Hand (DASH) as well as the Visual Analog Scale (VAS). Radiographic evaluation consisted of an anteroposterior and lateral film with the following parameters obtained at baseline and each study visit: dorsal and palmar tilt, radial height, radial inclination, ulnar variance, and osteoarthritis (OA) grade based on the Knirk and Jupiter scale.\[18\] Patients also underwent a clinical examination, which included grip strength and range of motion of the forearm, wrist, and fingers as measured by a trained research assistant. Finger range of motion was measured as the distance of fingertip to distal palmar crease in millimeters.

Stiffness of the hand was defined as fingertip to distal palmar crease distance greater than 1 cm for any one finger based on the distribution of data. We defined stiffness as a distance of 1 cm because this threshold represents less than 20% of the patient population, which is in line with the proportion of patients who complain of stiffness clinically. We felt that this group experienced a real clinical complication rather than simply a symptom of slower or less complete recovery. Furthermore, each patient was tested for grip strength using a dynamometer on the injured and uninjured side.

**Statistical Analysis**

Descriptive statistics were used to evaluate the occurrence of stiffness within the patient population. Differences in baseline patient characteristics between patients who experienced hand stiffness at some point in their recovery were assessed using Student’s t-tests for continuous data and Fisher’s exact tests for categorical data. Sociodemographic parameters that were assessed included age, OA grade at presentation, body mass index (BMI), education level, and gender. Other parameters evaluated included fracture pattern as determined by OTA classification, treatment method (operative fixation.
vs. nonoperative treatment), fixation method (external fixation vs. ORIF), and mechanism of injury (low energy vs high energy). Logistic regression analysis was used to evaluate which parameters were associated with the occurrence of stiffness while controlling for potential confounding variables. All statistical analyses were performed with SPSS version 19.0 software (SPSS, Inc, Chicago, Illinois), and significance level was set at \( p < 0.05 \).

### Results

Forty-nine of 260 patients (19%) of patients were considered “stiff” by our criteria at any time point during the 1-year follow-up. Patient demographics were similar in both groups (Table 1) with the “stiff” cohort having a greater mean age, \( p = 0.05 \). There was no significant difference in stiffness seen in operative cases versus nonoperative cases with the incidence being 19% in both groups. Within the group of patients that were operated on, there was no statistically significant difference in the occurrence of stiffness between the types of fixation used, such as ORIF, Ex-Fix, and pinning groups, \( p = 0.54 \). The mechanism of injury (low energy vs. high energy) or OTA classification also did not differ between the groups, \( p = 0.18 \) and \( p = 0.1 \), respectively.

Radiograph parameters including injury dorsal volar tilt, radial length, articular step off, and OA grading were not statistically different between the cohorts. However, injury ulnar variance was 3.1 mm (SD = 3.5) in the “stiff” cohort and 1.8 (SD = 2.9) in the “non-stiff” cohort, which was statically significant, \( p = 0.02 \).

### Predictors of Hand Stiffness

The logistic regression analysis used to identify factors associated with the occurrence of hand stiffness revealed that age and injury ulnar variance were the only factors that were associated with stiffness when controlling for all other factors. Body mass index (BMI), education level, gender, fracture pattern as determined by OTA classification, OA grade, treatment method (operative fixation vs. nonoperative treatment), fixation method (external fixation vs. ORIF), pre- or postoperative dorsal or palmar tilt, radial inclination, and radial height were not associated with development of hand stiffness at any point after fracture (Table 2).

### Effects of Hand Stiffness on Function

Functional disability, as measured by the DASH, did differ significantly (\( p = 0.001 \)) between stiff and non-stiff patients for both 6 month and 1-year follow-up points. Mean 6-month DASH score for “stiff” cohort was 29.3 (SD = 26.7) compare to 14.8 (SD = 18.6) for the non-stiff cohort. Mean 12-month DASH score for “stiff” cohort was 23.9 (SD = 21.7) compare

### Table 1  Patient Demographics

<table>
<thead>
<tr>
<th></th>
<th>Finger “Not Stiff” Cohort</th>
<th>Finger “Stiff” Cohort</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 211 (81%)</td>
<td>N = 49 (19%)</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>54 (17)</td>
<td>59 (14)</td>
<td>0.05*</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>26 (5)</td>
<td>26 (4)</td>
<td>0.5</td>
</tr>
<tr>
<td>Women</td>
<td>55%</td>
<td>73%</td>
<td>0.06</td>
</tr>
<tr>
<td>OTA Classification</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>A</td>
<td>44%</td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>21%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>35%</td>
<td>48%</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant, \( p < 0.05 \).

### Table 2  Predictors of Hand Stiffness

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-Value</th>
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<tr>
<td>Age</td>
<td>1.03</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>OTA Classification</td>
<td>1.12</td>
<td>0.7</td>
<td>0.63</td>
</tr>
<tr>
<td>Injury Dorsal Volar Tilt</td>
<td>0.99</td>
<td>0.97</td>
<td>0.26</td>
</tr>
<tr>
<td>Injury Radial Length</td>
<td>0.97</td>
<td>0.89</td>
<td>0.51</td>
</tr>
<tr>
<td>Injury Articular Step Off</td>
<td>0.72</td>
<td>0.44</td>
<td>0.2</td>
</tr>
<tr>
<td>Injury Ulnar Variance</td>
<td>1.21</td>
<td>1.05</td>
<td>0.01*</td>
</tr>
<tr>
<td>Injury OA Grading</td>
<td>0.81</td>
<td>0.23</td>
<td>0.74</td>
</tr>
<tr>
<td>Life Activity Status</td>
<td>1.1</td>
<td>0.82</td>
<td>0.54</td>
</tr>
<tr>
<td>Gender</td>
<td>0.73</td>
<td>0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>Operative/Nonoperative</td>
<td>1.74</td>
<td>0.66</td>
<td>0.27</td>
</tr>
</tbody>
</table>

95% Confidence Intervals (CI) reported as lower and upper bound. *Statistical significance, \( p = 0.05 \).
to 11.2 (SD = 16.7) for the non-stiff cohort. Linear regression analysis to see what factors where associated with DASH score showed that stiffness was significantly associated with 12-month DASH score (Table 3). Stiff patients were significantly more likely than non-stiff patients to have lower grip strength at 12-month (p = 0.001).

**Effects of Hand Stiffness on Pain**

Patients who experienced “stiffness” reported more pain at the 12-month follow-up, 2.1 (SD = 2.4) compare to 1.4 (SD = 2.1), although this was not statistically significant.

**Discussion**

In this study, we found positive ulnar variance at injury baseline and age were positive predictors for development of post-injury hand stiffness following distal radius fracture. OTA fracture classification did not influence the development of hand stiffness. Hand stiffness had a significant effect on recovery with respect to postoperative grip strength. There was also a trend toward higher pain levels in patients who experienced stiffness and those who did not, although this was not statistically significant. We did not find the presence of baseline OA to be a predictor of hand stiffness, which was a surprising finding. However, we did find that advanced age was a predictor of finger stiffness. Intuitively, this would make sense. Detecting subtle arthritic changes in the metacarpophalangeal and interphalangeal joints is difficult on plain radiographs, but as patients get older, joint stiffness is a universal finding and this correlated with our results.

Overall postoperative disability as measured by the DASH score was significantly lower for the “non-stiff” cohort compare to the “stiff cohort.” This was expected because many of the questions in the DASH ask about hand dexterity, such as the ability to cut food and perform other tasks.

Complications following distal radius fractures have been reported and include median nerve dysfunction, loss of reduction, posttraumatic arthritis, tendon irritation and disruption, and finger stiffness and infection. Many of these complications are well described, and their effect on outcome understandable. The mechanism for development of finger stiffness following distal radius fracture is not well understood and has been theoretically ascribed to over distraction of the carpus, hand position during immobilization, initial or surgical insult to the tendons crossing the wrist at the fracture site, development of a complex regional pain syndrome, or a combination thereof. We found no difference in the development of finger stiffness whether or not patients underwent operative treatment. One would expect that more severe fractures would have undergone operative treatment and that these patients would have sustained significantly more trauma to the wrist and carpus. Despite this fact, these patients did not exhibit an increased incidence of finger stiffness. Our nonoperative protocol was that patients were splinted or casted in such a way so that the palmar portion of the cast or splint was proximal to the distal palmar crease and that full flexion of the metacarpal phalangeal joints and interphalangeal joints was possible without impediment from the bulk of the cast or splint. Hand therapy for finger and forearm range of motion and edema control was started within a week of the injury. We found no difference in finger stiffness between patients treated by external fixation versus plating. Our protocol for external fixation ensured that full passive flexion was possible intra-operatively and that the carpus was not over distracted. All patients were started on hand therapy within a week of surgery or casting. For the cast and external fixation group, this involved finger and forearm range of motion exercises. The internal fixation group added wrist range of motion as well.

This early range of motion program may explain why the external fixation group did not show any additional finger stiffness when compared to the plate group, and also why a difference in finger stiffness was not found in the operative and nonoperative groups.

To our knowledge, this is the first report looking specifically at hand stiffness relative to distal radius fractures. Previous reports of distal radius fractures with regard to the hand

### Table 3 Predictors of Function as Measured by 12-Month Follow-up DASH Score

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>95.0% Confidence Interval for B</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative/Nonoperative</td>
<td>-4.585</td>
<td>-9.927</td>
</tr>
<tr>
<td>Stiffness Cohort</td>
<td>12.784</td>
<td>6.531</td>
</tr>
<tr>
<td>Age</td>
<td>.000</td>
<td>-.167</td>
</tr>
<tr>
<td>OTA Classification</td>
<td>-.944</td>
<td>-3.733</td>
</tr>
<tr>
<td>Accident Type</td>
<td>-.639</td>
<td>-2.787</td>
</tr>
<tr>
<td>Life Activity Status</td>
<td>.935</td>
<td>-.753</td>
</tr>
<tr>
<td>OA Grade</td>
<td>.200</td>
<td>-8.40</td>
</tr>
<tr>
<td>Gender</td>
<td>-4.405</td>
<td>-9.243</td>
</tr>
</tbody>
</table>

*Statistically significant, p < 0.05.
have been in the areas of hand assessment via a validated outcomes measurement tool, adherence to hand therapy, return to work, and complex regional pain syndrome.

Lyngcoln and colleagues found that adherence to hand therapy after distal radius fracture treatment led to improved short-term outcome. Outcome measures were change in impairment (wrist extension, grip strength, and pain rating) and change in activity (modified Levine questionnaire, Jebsen Test of Hand Function) from initial assessment (after cast removal) to follow-up (6 weeks later). Home exercise adherence was the most important predictor of the adherence measures. This study, however, did not specifically address hand stiffness.

MacDermid and coworkers prospectively followed a cohort of 227 workers with distal radius fracture for 12 months and reported on time lost from work, disability (PRWE, DASH), and health (SF-36). They found that work loss following DRF is highly variable and cannot be accurately predicted solely on the basis of clinical variables. Patients who have high self-reported pain or disability and occupational demand at baseline are at risk of prolonged work loss. We found that patients who developed clinically significant stiffness were less likely to be able to return to work. Thus, our study confirms the work of McDermid and coworkers.

Bickerstaff and Kanis reported on algodystrophy, currently renamed complex regional pain syndrome (CRPS), and distal radius fractures. They prospectively followed 274 patients and found 28% to have CRPS judged by the presence of bone pain or tenderness, vasomotor symptoms, and swelling and stiffness of the hand. Six months after injury, 80% still had stiffness. Failure to improve was associated with a significant loss of hand function (p < 0.0001). By 1 year, pain and tenderness, vascular instability, and swelling had decreased still further, but stiffness was still apparent in 50%.

Limitations of the current study include the measure of stiffness used to classify patients. “Tip to palm distance” may not be the only measure of finger stiffness. In our series, we chose this measure because it was easily reproducible under estimated the number of patients who were classified as “stiff.” We felt the fingertip to palm distance would take into account the ultimate summed result of TAM of the fingers. Although trained researchers followed a standard protocol for exam, “error of measurement” differences in tip to palm calculations could also have accounted for skewing of the groups. Finally, another limitation is that although this study demonstrated characteristics of patients with finger stiffness, it does not offer any particular treatment methods for treatment or avoidance. The incidence of chronic regional pain syndrome (CRPS) was not recorded, which would have impacted the development of hand stiffness. Another limitation of this study is in the relatively short follow-up of 1 year. Stiff patients were weaker and not back to full duty employment at 1 year; longer follow-up would be needed to ascertain whether and when these patients regained their grip strength and returned to full duty work. No specific test for hand function test (i.e., Jebsen-Taylor Hand Function Test) was used for more objective hand functional data.

In summary, advanced patient age and injury ulnar variance were positive predictors for developing postoperative hand stiffness following fracture of the distal radius. Fracture pattern did not influence the development of hand stiffness. Hand stiffness had a significant effect on recovery and return to work and on grip strength. Identification of these patients at risk will enable treating physicians to implement early intervention strategies aimed at reducing the incidence of this complication. However, even with the most appropriate proactive treatment for this patient population, the expected outcome should be adjusted for the patient and treating physician.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References


