Changes in Impairment and Function after Static Progressive Splinting for Stiffness After Distal Radius Fracture

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ABSTRACT: The purpose of this study was to describe changes in range of motion, grip strength, and function in subjects treated with static progressive splinting for stiffness after distal radius fracture. A retrospective review was conducted on 25 patients; outcomes reviewed included wrist/forearm motion, grip strength and Disability of the Arm, Shoulder, and Hand (DASH) scores. The Wilcoxon-Signed Rank test was used to assess differences between pre-/postsplinting outcome measurements. Spearman correlation coefficients were calculated for the DASH scores with each of the other measurements. Wrist extension and flexion improved 18.6 (p < 0.0001) and 11.4 degrees (p < 0.0001), respectively. Forearm pronation and supination improved 20.0 (p < 0.0001) and 14.5 degrees (p < 0.0001), respectively. Grip strength improved 24.5 pounds (p = 0.0012). The median DASH score improved from 43 to 19 (p < 0.0001). DASH scores demonstrated a significant negative correlation with wrist extension (r = −0.50, p = 0.011) and forearm supination (r = −0.47, p = 0.02). Increased wrist extension and supination correlated with better functional outcome as reflected by the DASH scores.


Restoration of wrist and forearm range of motion (ROM), strength, and function are among the primary goals of rehabilitation after distal radius fracture. Appropriate management of a wrist fracture often entails immobilization of the wrist and/or forearm. Immobilization and the edema associated with the trauma often results in biochemical, mechanical, and physiologic changes of connective tissue including, joint capsule, ligaments, and musculotendinous tissue, which may consequently lead to soft-tissue shortening and joint stiffness.1 Early controlled stretching of this shortened soft tissue is an important aspect of treating joint stiffness after fractures. Permanent elongation of shortened soft tissue that limits joint motion can be successfully achieved with the application of controlled stress to restore normal viscoelasticity of the connective tissue.1 Static progressive splinting (SPS) is an established treatment technique effective in lengthening soft tissue by applying controlled stress through mechanical devices such as splints.2–4 Use of splints to provide controlled end-range force for prolonged periods of time to promote lengthening of contracted soft tissue is established in the literature.5–11 However, more information is needed on the use of SPS to increase motion at the wrist and forearm after distal radius fracture.

Impairments in ROM and strength after distal radius fractures may lead to difficulty with functional tasks.12–14 Ratings of disability are often based on measurements of ROM and strength; yet, much speculation exists about whether deficits in these are truly related to a person’s perceived ability to function.15–17 More information is needed about the relationship between the impairments of wrist ROM and/or strength and functional disability in people with healed distal radius fractures.

The purpose of this study was to retrospectively describe the relationship between improved ROM, grip strength, and upper extremity functional outcomes as measured by the Disability of the Arm,
shoulder, and hand (DASH) in subjects treated with SPS for wrist or forearm stiffness after healed fractures of the distal radius. It was hypothesized that an improvement in wrist and/or forearm ROM and grip strength after the application of an adjunctive stretching device in distal radius fracture patients would improve their functional outcomes.

METHODS

A retrospective review of medical records was conducted in patients with residual stiffness after distal radius fractures that were treated at the medical center between January 2001 and April 2005. The institutional review board approved the study protocol. Study subjects were individuals with healed distal radius fractures who received hand therapy and a prefabricated forearm-based SPS from a single manufacturer (Joint Active Systems, Inc., Effingham, IL) for management of wrist and/or forearm stiffness. Individuals selected to use the SPS by their treating therapist had demonstrated osseous union, no neurovascular deficits and had reached a plateau or lost ROM gains despite therapeutic intervention after standard treatment guidelines for distal radius fractures.18,19 Due to the retrospective nature of the study, no standard parameters were used to prospectively define a plateau in progress.

Subject data were included in the analysis if the subject 1) sustained a fracture of the distal radius; 2) had been treated for wrist or forearm stiffness with a SPS device; 3) was skeletally mature; and 4) had completed the SPS treatment at the time of the review. Subject data were excluded from analysis if 1) the SPS device was discontinued earlier than the therapist or physician recommended; 2) ROM impairments were not recorded immediately prior and after splinting program; and 3) the wrist or forearm motion deficits were present before the wrist injury to the degree that it affected the patient’s daily activity.

Subjects

Out of 249 patients with distal radius fractures seen in the hand therapy clinic between January 2001 and April 2005, a total of 38 patients were treated with a SPS device and only 25 patients met the inclusion and exclusion criteria of this study (Table 1). There were 10 females and 15 males with 14 right and 11 left wrists involved. Of the 23 right-handed individuals, 9 injured their nondominant extremities and 14 injured their dominant extremities. Of the two left-handed

<table>
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<tr>
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<th>Sex</th>
<th>Age</th>
<th>Inv</th>
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<th>Occupation</th>
<th>Insurance</th>
<th>Days from Inj to Splint</th>
<th>Total # Therapy Visits</th>
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M = male; F = female; Dom = dominance; Inv = involved; P = private; WC = workers compensation; MR = Medicare; MC = Medicaid; PP = personal pay; L = liability; Immobl = immobilization; Inj = injury; Tx = treatment; F/E = flexion/extension splint; P/S = pronation/supination splint; Ext Fix = external fixation; ORIF = open reduction internal fixation; BP = bridge plate; AAO = arthroscopic assisted osteosynthesis.
individuals, both involved their dominant extremities. The mean age was 46 years (range, 18–68).

Two of the distal radius fractures were associated with scaphoid fractures. Ten patients were treated with external fixation, 12 underwent open reduction internal fixation, 2 had bridge-plating placement as described by Ruch et al., and 1 had arthroscopic-assisted osteosynthesis for the distal radius fracture. For the patients with external or bridge-plate fixation, wrist motion was initiated on the removal of the external fixator or bridge plate after fracture healing.

All patients were individually fitted and instructed in the use of the splint following the manufacturers recommended guidelines. The participants were instructed to statically position the joint as close to the end-range as comfort would allow. The joint position was then readjusted by the subject to position the tissue at its new maximum tolerable length. During the first week, patients were instructed to perform one 30-minute session per day, increasing to two 30-minute sessions per day in the second week and three 30-minute sessions per day for the remaining weeks.

Outcome data including wrist active ROM (flexion and extension), forearm active ROM (pronation and supination), isometric dynamometry including grip strength at the third handle position, and DASH scores were recorded. The DASH Questionnaire is a standardized survey, which assesses the patients’ perspective of their functional status. Scores produced by the DASH range from 0 to 100; the lowest score indicates no functional disability and the highest score indicates severe disability. Each outcome measure was obtained before treatment with the SPS and after the completion of splinting. Standardized methods as described by the American Society of Hand Therapists for collecting grip/pinch strength and ROM measurements were followed by all physical and occupational hand therapists as a part of department policy. Validation and reliability of standardized grip and ROM measurements collected have been previously established. A total of eight therapists were involved in the care of these patients. Most but not all, subject’s measurements were taken by the same treating therapist throughout the course of treatment. There were a few cases (n = 4) where the treating therapist changed employment and a new treating therapist collected the remaining data according to the records.

The average time before the initiation of wrist ROM in this sample after distal radius fracture was 47 days (range, 13–81). The mean time from injury to the initiation of SPS was of 94 days (range, 48–188). The mean duration of SPS use was 75 days (range, 14–160). These subjects on average received a total of 23 visits in hand therapy. Six patients received a forearm pronation/supination splint; 19 patients received a wrist flexion/extension splint. No patient received combined splinting for forearm pronation/supination and wrist flexion/extension.

**Statistical Analysis**

The Wilcoxon-Signed Rank test was used to assess differences between pre- and postsplinting outcome measurements. Spearman correlation coefficients were calculated for the DASH scores with each of the other measurements. Means were reported with standard deviation in the results; for the DASH, the median and the 25th and 75th percentiles were also reported. Analyses were performed for the entire sample and separately for subjects who received the forearm and the wrist brace. The SAS software version 9.1.3 (Cary, NC) was used for all analyses. Outcome measures with an observed p-value less than 0.05 were considered to be statistically significant.

**RESULTS**

After SPS, the mean wrist extension and flexion increased 18.6 and 11.4 degrees, respectively; the mean forearm pronation and supination increased 20.0 and 14.5 degrees, respectively. The average grip strength increased 24.5 pounds. All measured improvements were significant when analyzed by the Wilcoxon-Signed Rank test (Table 2). When examined separately, the 19 subjects who used the wrist flexion/extension splint and the 6 subjects who used the forearm rotation splint all gained ROM in both the wrist and in the forearm (Tables 3 and 4).

The median DASH score, a measure of perceived disability, improved from 43 to 19 after SPS therapy (p > 0.0001). Spearman correlation coefficients (r) were calculated for the DASH score with each of the other measures (Table 5). DASH scores demonstrated a significant negative correlation with wrist extension (r = −0.50, p = 0.01), forearm supination (r = −0.47, p = 0.02), and a borderline significant negative correlation with forearm pronation (r = −0.39, p = 0.053) at final follow-up, which indicates a better functional result.

**DISCUSSION**

Hand therapy can be a vital part of the treatment in patients after distal radius fracture in improving wrist ROM, strength, and quality of life and should be individualized to meet patients’ specific needs. The current retrospective study demonstrates that this cohort of distal radius fracture patients suffering from posttraumatic joint stiffness showed improved wrist and forearm ROM, strength, and upper extremity function after splint treatment.
Although most distal radius fracture patients treated at the medical center regained adequate ROM and strength after routine hand therapy, a small subset of patients did not recover adequate ROM, strength, and function within a reasonable time frame and required more intensive physiotherapeutic interventions, including SPS. The medical chart review in the current study revealed that the intensity of treatment with the hand therapist varied, ranging from a onetime visit only to rigorous multiple-session intense therapies depending on the degree of difficulty of the patient in regaining ROM and strength after distal radius fracture. Less than 10% of the patients demonstrated difficulty in regaining wrist or forearm ROM. This finding is in accordance with several other studies that most patients who sustain distal radius fractures recover with adequate ROM, strength, and function within a relatively rapid period of time.32

Traditional measures of ROM and strength impairment are valuable in providing objective tools reflecting the physiologic and functional recovery after wrist fractures. However, the correlation between these measurable parameters and patient’s self-reported functional deficits after healed wrist fractures has not yet been firmly established. Several studies have been conducted on normal subjects examining the effects of artificially induced ROM limitations (through use of a splint) of the wrist for functional tasks.41–43 Other studies have been conducted without constraints to examine the wrist motion needed for functional tasks.44,45 The functional range of wrist/forearm motion necessary to perform most activities of daily living has been reported to be 5–40 degrees of wrist flexion, 30–40 degrees of wrist extension, and 50 degrees each of forearm supination and pronation.46–48

### TABLE 2. Average Wrist/Forearm ROM, SDs, and Wilcoxon-Signed Rank Test (n = 25)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Mean (SD)</th>
<th>Post-Mean (SD)</th>
<th>Post-Pre Diff (SD)</th>
<th>p-Value for Diff</th>
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</thead>
<tbody>
<tr>
<td>Wrist extension</td>
<td>24.3 (18.4)</td>
<td>42.9 (14.2)</td>
<td>18.6 (14.0)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Wrist flexion</td>
<td>30.1 (9.9)</td>
<td>41.6 (10.8)</td>
<td>11.4 (11.3)</td>
<td>&lt;0.0001</td>
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<td>Supination</td>
<td>49.0 (25.1)</td>
<td>62.3 (21.1)</td>
<td>13.4 (16.1)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Pronation</td>
<td>49.5 (27.0)</td>
<td>69.5 (15.8)</td>
<td>20.0 (23.9)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Grip strength</td>
<td>23.9 (17.6)</td>
<td>44.4 (19.6)</td>
<td>24.5 (18.0)</td>
<td>0.0012</td>
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</table>

ROM = range of motion; SD = standard deviation; Diff = difference between postsplint and presplint measurements.

### TABLE 3. Average ROM (Standard Deviation) in Subjects Wearing SPS Wrist Flexion/Extension Splint (n = 19)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Mean (SD)</th>
<th>Post-Mean (SD)</th>
<th>Post-Pre Diff (SD)</th>
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<tr>
<td>Wrist extension</td>
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<td>42.9 (14.2)</td>
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<td>Wrist flexion</td>
<td>29.6 (10.4)</td>
<td>41.0 (9.0)</td>
<td>11.4 (9.0)</td>
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<td>Forearm supination</td>
<td>48.9 (24.6)</td>
<td>62.4 (20.9)</td>
<td>13.5 (20.9)</td>
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<tr>
<td>Forearm pronation</td>
<td>54.8 (26.2)</td>
<td>72.8 (11.5)</td>
<td>18.0 (11.5)</td>
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</table>

ROM = range of motion; SPS = static progressive splinting.

Adams et al.41 and Goldfarb et al.49 in separate studies found that subjective outcome measures as measured by the DASH questionnaire had a tendency to worsen with a reduction in the ROM of the forearm and wrist. The DASH outcome questionnaire has been determined to be a valid measure of health status useful in patients with a wide variety of upper extremity complaints including those with wrist trauma.50–52 The DASH has been shown to correlate with ROM measures, to discriminate well between patients who are working or not and to be responsive to changes in function in response to treatment interventions.50,51,53

In the current study, a negative correlation was demonstrated between DASH scores and wrist extension, pronation, and forearm supination. This increase in motion after splinting therapy was associated with an improved DASH score reflecting a better functional result. A similar negative correlation between DASH scores and these measures was noted by Goldfarb et al. in an average 2.8-year follow-up study on patients with healed both bone forearm fractures.49 However, in that study, significant negative correlations were also discovered between the DASH and wrist flexion. In contrast, our study did not reveal a significant correlation between DASH scores and wrist flexion. One possible explanation is that the pretreatment average wrist flexion in this study was 30 degrees, which might be good enough to perform most of the daily tasks as reflected by DASH score.

Using a different self-reported outcome measure, the Patient-Rated Wrist Evaluation score (PRWE), Karnezis et al. demonstrated that forearm rotation and flexion and extension of the wrist were not

### TABLE 4. Average ROM (Standard Deviation) in Subjects Wearing SPS Forearm Pronation/Supination Splint (n = 6)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-Mean (SD)</th>
<th>Post-Mean (SD)</th>
<th>p-Value for Diff</th>
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<td>Wrist extension</td>
<td>33.7 (15.2)</td>
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<td>31.7 (8.7)</td>
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<td>Forearm supination</td>
<td>49.5 (29.3)</td>
<td>62.2 (23.7)</td>
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<td>Forearm pronation</td>
<td>32.7 (23.6)</td>
<td>39.2 (23.5)</td>
<td>&lt;0.0001</td>
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ROM = range of motion; SPS = static progressive splinting.

### TABLE 5. Spearman Correlations with the DASH score (n = 25)

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<tr>
<td>Pronation</td>
<td>–0.11</td>
<td>0.61</td>
<td>–0.39</td>
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<tr>
<td>Supination</td>
<td>0.12</td>
<td>0.56</td>
<td>–0.47</td>
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<td>Grip strength</td>
<td>0.11</td>
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</tbody>
</table>

DASH = Disability of the Arm, Shoulder, and Hand; Corr = correlation; Pre = before splint initiation; Post = after splint initiation.
significantly associated with perceived functioning. Furthermore, grip strength was shown to be a more significant predictor of the PRWE score and thus appeared to be a sensitive indicator for returning of wrist function. Studies investigating the relationship between impairment and disability by MacDermid and colleagues have determined that carrying weight is the most difficult task for patients suggesting that strength is correlated to functional ability.

We recorded the changes in grip strength that occurred after using the splint. Several studies have demonstrated that as positions of the wrist and forearm change, grip strength is affected. Although the position of the forearm was controlled during grip strength measurements, the wrist was allowed to be in a self-selected position. Greater mobility of the wrist in the sagittal plane may explain the increases in grip strength that occurred in this sample; however, none of these subjects had reached a plateau in grip strength at the time of splint initiation. Therefore, similar changes in grip strength may have occurred simply due to the effects of time and additional exercises without the use of a splint.

In this study, impairments in grip strength did not correlate significantly with patients’ perceived functional ability (p = 0.067). The weak correlation between grip strength with DASH scores has been reported by Goldfarb et al. The lack of strong correlation between grip strength with the DASH may indicate a diminished sensitivity of the DASH questionnaire in detecting functional strength impairment in distal radius fracture patients when compared to the PRWE. The PRWE may be more sensitive to grip strength changes because it is specific for wrist pathology, whereas the DASH is used for broader upper extremity joint dysfunctions. Both have been used extensively for the upper extremity functional outcome measurements.

Overall, this cohort demonstrated improved stiffness in wrist and forearm, grip strength and functional outcome measurements after splinting treatment. More importantly, these results demonstrate that as wrist extension, forearm pronation, and supination increased, subjects reported better functional outcome as reflected by the DASH scores. The current study was limited by the small sample size, the retrospective design, and the fact that multiple examiners collected the data using standardized methods of measurements. The study was also limited by the difference in location of distal radius fracture, mechanism of injury, method of medical management, and associated injuries. Likewise, the dosage of stress to each individual during SPS could not be precisely monitored; therefore, the impact of total end-range time on the variably restricted tissues cannot be adequately assessed. The efficacy of splinting also cannot be assessed formally without a control group; therefore, using a prospective design with a control group would have strengthened the study significantly. In conclusion, this retrospective data suggest that the SPS can be a useful adjunct to therapy in the treatment of posttraumatic stiffness after distal radius fracture. Furthermore, increased wrist ROM correlates with better functional outcome as reflected by the DASH scores.

REFERENCES


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#1. The authors concluded that there was a correlation between
   a. the DASH scores and TERT values
   b. the DASH scores and the length of pre-splinting immobilization
   c. better function and increased wrist extension and supination ROM
   d. better function and increased wrist flexion and pronation ROM

#2. The study design was
   a. retrospective
   b. prospective
   c. randomized clinical trials
   d. comparative case reports

#3. The subject population consisted of patients with
   a. only Frykman type I fractures
   b. only Frykman type II fractures
   c. only distal radius fractures
   d. either a distal radius fracture alone or a distal radius plus an ulnar styloid fracture

#4. The specifications of the splint were described
   a. in great detail
   b. on a case by case basis
   c. simply as a static progressive splint
   d. in a way that the reader could readily duplicate the splint

#5. The authors concluded that the DASH was superior to the PRWE tool as a wrist outcome measure
   a. true
   b. false

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