NEWLY DEVELOPED DYNAMIC SPLINT VS. DYNAMIC OUTRIGGER SPLINT FOR POSTOPERATIVE TREATMENT OF EXTENSOR TENDON RUPTURE IN PATIENTS WITH RHEUMATOID WRISTS: A PRELIMINARY STUDY

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Abstract. Aim and object of the study: Extensor tendon rupture in patients with rheumatoid wrists causes dysfunction of the hand and necessitates tendon reconstruction and surgical treatment of the wrist joint. Dynamic outrigger splints using rubber bands have been used for early postoperative mobilization of the fingers. However, these splints are bulky and cause discomfort. We developed a new dynamic splint, which is compact and uses torsion springs instead of the rubber bands used in conventional outrigger splints. The splint extends the metacarpophalangeal joints using a volar finger bar. The objective of this study was to compare the clinical outcomes and subjective assessments between patients treated with the two types of splint. Methodology: Fourteen wrists (14 patients) were included. Clinical outcomes (range of active motion of the metacarpophalangeal joint) and subjective assessments were investigated in patients treated with either an outrigger splint or our new dynamic splint. Results: There were no differences in clinical outcomes between patients treated with the two kinds of splint. The new splint performed better in terms of the subjective assessment of changing clothes and bulkiness. Conclusions: The new splint yielded equivalent clinical outcomes and better subjective assessments compared to conventional outrigger splints due to its reduced size.

Key words: newly developed dynamic splint, dynamic outrigger splint, extensor tendon rupture, treatment

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic autoimmune disease characterized by progressive systemic inflammation. RA primarily affects the lining of the synovial joints and destroys both articular cartilage and subchondral bone, leading to functional limitations and disability [1].

Spontaneous extensor tendon rupture in patients with a rheumatoid wrist is a complication of RA. Tendon rupture often affects the ulnar fingers, especially the little finger, leading to immediate dysfunction of the hand and the need for tendon reconstruction and treatment for distal radioulnar joint (DRUJ) in most patients [2, 3].

After surgery for extensor tendon injuries, the fingers are immobilized for a few weeks, after which exercise is allowed [4-6]. Before 2000, some authors reported that early finger motion exercises could result in earlier recovery, a shorter period of rehabilitation, and lower costs than immobilization therapy [7-9]. Early movement programs are also beneficial to the repaired tendon, both biomechanically and biochemically [9]. Postoperative therapy tends to involve a dynamic outrigger splint with rubber bands to allow active flexion and passive extension of the fingers [7-9]. However, based on our experience, outrigger splints are large and patients complain about the discomfort, possible trauma, poor appearance, and presence of a large outrigger bar on the dorsal side of the splint making it difficult to change clothes. With these complaints in mind, we developed a new dynamic splint with the aim of improving patient subjective assessments. The purpose of this study was to compare the clinical outcomes and subjective assessments between patients treated with either our new dynamic splint or a traditional outrigger splint.

MATERIALS AND METHODS

We retrospectively reviewed the clinical data of patients who were diagnosed with RA and under-
went surgery for extensor tendon reconstruction and treatment of the distal radioulnar joint for extensor tendon ruptures at the wrist. We performed verbal or written analysis of patients' subjective assessments during splint use. We could not make contact with 11 patients because of relocation or death. This study included the remaining 14 patients (14 wrists). Written informed consent for publication was obtained from all patients, and the study was approved by the institutional review board of our institution.

Surgical procedures
Surgical procedures were performed under general or local anesthesia using air tourniquet control. A dorsal incision over the wrist was made. The extensor retinaculum was incised using a step-cut method through the 5th compartment to the 4th compartment. The extensor tendons were exposed and the synovium around the healthy and free ends of the tendons was removed. The excursion of the proximal end of the ruptured tendons was assessed by pulling distally. When the excursion was 15-20 mm, the condition of the proximal stump was judged as the available amplitude of the muscle, a tendon graft was selected as a reconstruction method, and the palmaris longus was harvested. When the excursion was poor, different reconstruction methods, i.e. tendon transfer and end-to-side suture technique (the distal end of the ruptured tendon was sutured to the adjacent extensor tendon) were selected. Thereafter, procedures for the wrist joint and DRUJ were performed based on the preoperative radiograph and instability of the wrist, namely the Sauvé-Kapandji procedure, Darrach procedure, and total wrist fusion [10, 11]. Tendon reconstruction was then performed using an interlacing suture for all tendons. The dorsal capsule was repaired. The extensor retinaculum was repaired by lengthening and placed over the tendons to prevent bowstringing. The wrist and fingers were covered by bulky dressing and the wrist and MCP joints were immobilized in the neutral position and at 0° of extension, respectively.

Postoperative therapy and dynamic splints
At 2 days after surgery, the splint was applied and passive extension by dynamic assistance and active flexion of the fingers were started under instruction by a hand therapist during hospitalization. Two kinds of splint were used. A conventional-type dynamic outrigger splint was used in eight patients (group O), whereas a newly developed dynamic splint assisted by torsion springs was used in six patients (group T). The former splint had been used until February 2006, whereas the latter had been used since March 2006. The former splint was forearm-based and included an outrigger with rubber bands (Fig. 1A). Four rubber bands were attached to the index to little fingers. The tension of each band could be adjusted by the length and thickness of the rubber band for each finger independently (Fig. 1B, C). The latter splint was forearm-based and included a bar and torsion springs (Fig. 2A). This was custom-made splint made by orthotist. The torsion springs were made of piano wire and the thickness and winding number of the springs were adjusted depending on the strength of grip and finger extension of the patient before surgery. The finger bar was located volar to the proximal phalanx of the fingers and the springs acted to bring the fingers into the extended position at the MCP joint (Fig. 2B, C). The bar was on a uniform plane and its strength was adjusted by the springs. As such, the tension could not be adjusted for each finger independently. Except for sleeping, the patients put on the splint. At night, the wrist and fingers were immobilized in neutral and extended

Fig. 1. Conventional dynamic outrigger splint
(A) Appearance of the splint. The splint is forearm-based and consists of the outrigger bar with rubber bands. (B) Dorsal view of the splint. Rubber bands attached to the proximal fingers extend the metacarpophalangeal joints of the fingers. (C) Volar view of the splint. Rubber bands attached to the proximal fingers.
positions, respectively, using another static splint. Massage was started at 2 weeks after surgery to reduce edema. Once self-training was possible, rehabilitation was performed at an out-patient clinic. The splint was removed and active motion of the MCP joint and wrist joint was started at 6 weeks after surgery. Free use of the hand was allowed at 3 months after surgery.

**Objective and subjective assessments**

Objective outcomes for tendon reconstruction were assessed by the active range of motion of the MCP joint at the final follow-up. They were evaluated using a standard goniometer and classified by Gelmacher’s criteria, as modified by Sakuma et al. [12, 13]. The criteria were categorized into three groups: good = an active flexion arc ≥ 45° and an extension lag < 20°, fair = an active flexion arc ≥ 45° and an extension lag 20-40° or an active flexion arc < 45° and an extension lag < 20°, or poor = an active flexion arc < 45° and an extension lag 20-40° or an extension lag ≥ 40°.

We performed subjective assessments of patients treated with the two types of splint. The items assessed were as follows: general performance of rehabilitation (difficult/moderate/easy), changing clothes (difficult/moderate/easy), eating meals (difficult/moderate/easy), finger flexion exercise (difficult/moderate/easy), finger extension exercise (difficult/moderate/easy), and bulkiness of the splint (large/moderate/good). Each item was classified into three stages and scored. Poor assessments were given scores of 0 and good assessments scores of 2. We showed both splints to the patients and asked them which they would select for future therapy. Patient satisfaction with splint therapy was scored by the patients themselves using a visual analog scale: i.e. no satisfaction (0) to full satisfaction (100).

**Statistical analysis**

Statistical analysis was performed as follows. To analyze the objective outcomes and subjective assessments, each finger and patient was included, respectively. To analyze objective outcomes, we combined the fair and poor groups. To analyze subjective outcomes, the responses with scores 1 and 2 were combined. Differences between the groups were assessed by the chi-square test or Mann-Whitney U-test. Fisher’s exact test was also used where appropriate. Statistical significance was set at p < 0.05.

**RESULTS**

**Demographic data of the patients (table 1)**

There were 13 women in the final cohort. The average age of the patients at surgery was 53 (range: 30-79) years. The average duration after diagnosis with RA was 8.7 (range: 1-21) years. The average Larsen grade of the affected wrist was 4.0 (range: 2-5), whereas that of the affected metacarpophalangeal (MCP) joint was 1.6 (range: 0-4) [14]. The right side was involved in 11 patients and the left in 3 patients. The average number of fingers with ruptured extensor tendons was 1.9 (range: 1-3). The average duration from symptoms of tendon rupture to surgery was 8.8 (range: 1-84) months. Surgical procedures for DRUJ were the Sauvé-Kapandji procedure in 8 patients, Darrach procedure in 3 patients, and total wrist fusion in 3 patients. Tendon reconstructions were end-to-side suturing in 19 fingers, tendon transfer in 1 finger, and tendon graft in 7 fingers.
Clinical characteristics of the patients

For objective outcomes, nine fingers had good, five had fair, and one had poor results in group O. Nine fingers had good and three had fair results in group T (p = 0.70, Table 2). All fingers with fair and poor results in group O and two of three fingers with fair results in group T had multiple affected fingers (rate of “good”: single; 6/7, multiple; 12/20, p = 0.36). The average extension range of the MCP joint of the little finger was -4.4° (range: 30 to -30) in group O and -8.7° (range: 0 to -20) in group T, whereas the average range of flexion was 76.9° (range: 40 to 90) in group O and 64° (range: 35 to 85) in group T (p = 0.85, 0.21, respectively). The average extension range of the MCP joint of the ring finger was -11.7° (range: 0 to -30) in group O and -3.3° (range: 0 to -20) in group T, whereas the average range of flexion was 75.8° (range: 30 to 90) in group O and 71.7° (range: 60 to 85) in group T (p = 0.18, 0.20, respectively). The extension range of the MCP joint of the middle finger was -30° in group O and -20° in group T, whereas the range of flexion was 70° in group O and 80° in group T (one finger in each group).

Table 1. Demographic data of the patients

|                | Outrigger splint (group O) | New dynamic splint (group T) | p-value |
|----------------|----------------------------|-------------------------------|---------|
| Number         | 8                          | 6                             |         |
| Age (years)    | 47 (30-63)                 | 62 (37-76)                    | 0.07    |
| Sex            | male: 1, female: 7         | female: 6                     | 1       |
| Injured side   | right: 7, left: 1          | right: 4, left: 2             | 0.54    |
| Disease duration (years) | 11 (5-21) | 8 (1-10)                      | 0.24    |
| Larsen grade of the affected wrist joint | 4.4 (3-5) | 3.5 (2-4)                  | 0.13    |
| Larsen grade of the affected MCP joint | 2.0 (1-4) | 1.2 (0-2)                  | 0.10    |
| Surgical delay (months) | 12.8 (1-84) | 2.3 (1-4)                   | 0.84    |
| Number of fingers affected | one: 3, two: 3, three: 2 1.9 (1-3) | one: 1, two: 4, three: 1 2.0 (1-3) | 0.78    |
| Surgical procedure for the wrist |         |                               | 0.23    |
| Sauvage-Kapandji procedure | 3         | 5                             |         |
| Darrach procedure | 2         | 1                             |         |
| Total fusion   | 3                          | 0                             |         |
| Methods of tendon reconstruction |         |                               | 0.51    |
| End-to-side suturing | 9         | 10                            |         |
| Tendon transferb | 1         | 0                             |         |
| Tendon graftsc | 5                          | 2                             |         |

The values are expressed as average (range). *The number of the methods for tendon reconstruction included multiple procedures. aExtensor index proprius. bPalmaris longus. MCP, metacarpophalangeal.

Table 2. Objective outcomes after treatment

|                | Outrigger splint (group O) | New dynamic splint (group T) | p-value |
|----------------|----------------------------|-------------------------------|---------|
| Objective outcomes | Good Fair Poor | Good Fair Poor |         |
| 15 fingers       | 9 5 1                | 9 3 0                       | 0.70    |
For subjective assessments, there were statistically significant differences in changing clothes and bulkiness of the splint between the two types of splint, with the new splint receiving fewer “difficult or large” responses (Table 3). There was no significant difference in the selection of the different splints for future therapy and satisfaction with splint therapy between patients treated with the two types of splint.

**Table 3. Subjective assessments after treatment**

| Subjective assessments          | Outrigger splint (group O) | New dynamic splint (group T) | p-value |
|--------------------------------|-----------------------------|-----------------------------|---------|
|                                | easy            | moderate | difficult | easy            | moderate | difficult |         |
| General performance of         | 2              | 4        | 2         | 0              | 2        | 4         | 0.28    |
| rehabilitation                 |                |          |           |                |          |           |         |
| Changing clothes               | 0              | 0        | 8         | 0              | 4        | 2         | 0.02    |
| Eating meals                   | 0              | 2        | 6         | 0              | 5        | 1         | 0.10    |
| Finger flexion exercise        | 2              | 4        | 2         | 1              | 4        | 2         | 0.47    |
| Finger extension exercise      | 2              | 5        | 1         | 1              | 1        | 1         |         |
| Bulkiness of the splint        | 0              | 0        | 8         | 1              | 3        | 2         | 0.02    |
| Splint selection for future    | O: 2, T: 6     | T: 6     |           |                |          |           |         |
| therapy (O vs. T)              |                |          |           |                |          |           |         |
| Satisfaction (VAS)             | 57.4 (12–96)   | 63.8 (46–83) |          |                |          |           | 0.85    |

The values are expressed as the average (range). O: conventional dynamic outrigger splint, T: dynamic splint assisted by torsion springs. VAS: visual analog scale.

**DISCUSSION**

In this study, we investigated the efficacy of a newly developed dynamic splint assisted by torsion springs for the postoperative treatment of extensor tendon ruptures in patients with RA. This new system is different from the conventional outrigger splint in that the bar is replaced with a volar finger bar, reducing the bulkiness on the dorsal side and making the new splint more compact. This retrospective continuous study revealed that this new splint did not reduce finger motion and yielded better results for the subjective items changing clothes and bulkiness of the splint when compared to a traditional outrigger splint.

There were concerns regarding extension contracture (especially with respect to the ulnar fingers when treated with our new splint) because it was not possible to adjust each finger individually. However, there was no difference in the movement of the little finger between the two splints. A previous study showed that tendon excursion to minimize adhesion at the repaired site was 5 mm [15]. For 5 mm of tendon gliding, approximately 40° of MCP joint motion of the little finger is necessary, depending on the moment arm [16]. Careful attention and instruction for finger motion were provided to patients to prevent extension contracture and adhesion of the extensors. With these considerations in place, the new splint achieved both compact size and acceptable finger motion.

There were no significant differences in terms of which splint patients selected for future therapy and satisfaction with splint therapy between patients treated with the two kinds of splint, although only two of eight patients in group O selected outrigger splint. From these results, it appears that the patients were not completely satisfied by the new splint. The items that patients were unsatisfied with (defined based on half of patients giving a score of 0 or 1) were “general performance of rehabilitation”, “changing clothes”, “eating meals”, “bulkiness of the splint”, and “finger flexion exercise”. Generally, patients with RA have very poor grip strength due to joint destruction, disability in other joints, and illness. With the above in mind, further improvement of our new splint is desirable in the future through the following: weight reduction by using different materials or altering the strength of the spring postoperatively.

In this study, 60% of patients with multiple tendon injuries experienced fair and poor objective outcomes in both splint groups. A previous study also
showed similar results: postoperative finger motions were worse in patients with multiple extensor ruptures than in those with a single rupture [4, 5, 13]. Sakuma et al. reported that the number of ruptured extensor tendons was significantly correlated with the results of tendon reconstruction and significantly associated with preoperative surgical delays [13]. We agreed with their recommendation that early surgical intervention in the treatment of extensor tendon ruptures with RA wrists is important to improve outcomes.

This study has several limitations that should be mentioned. First, the number of patients was small. Second, the follow-up rate was 44%. Third, the backgrounds of the patients were different, including surgical procedures. This might have been affected by the period in which surgery was performed. Moreover, group O included patients with total wrist fusion. Because the effect of tenodesis at the wrist joint is ameliorated by fusion, the range of motion at the MCP joint might have decreased.

In conclusion, we developed a new dynamic splint assisted by torsion springs for the postoperative treatment of extensor rupture in RA wrists by removing the dorsal outrigger from an outrigger splint and instead using a torsion spring to make the system more compact. Our new splint provided equal active range of motion of the MCP joint compared to conventional dynamic outrigger splints. Subjective assessments revealed that the new splint was superior to conventional outrigger splints in terms of changing cloths and bulkiness, which are two of the main complaints of patients treated using these splints. This new splint could lead to improved patient quality of life during treatment.

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No parts of the article, including ideas, texts, and graphics are copied from elsewhere.

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