CONTROLLED MOTION REHABILITATION AFTER FLEXOR TENDON REPAIR AND GRAFTING

A MULTI-CENTRE STUDY

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We present a system for treatment by controlled motion after repair of flexor tendons in the hand. This Washington regimen incorporates both controlled active extension against passive flexion by rubber band and the use of controlled passive extension and flexion. We utilise the Brooke Army Hospital modification of the rubber band passive flexion splint; this provides for maximal excursion of the tendon with full passive flexion of the finger. The 66 patients (78 fingers) who form the basis of this study all sustained complete laceration of the flexor profundus and superficialis tendons in "no man's land".

Results were evaluated by the Strickland formula of total active motion (TAM) of the proximal and distal interphalangeal joints. Sixty-two fingers (80%) were rated "excellent", 14 fingers (18%) were "good", two fingers (2%) were "fair", none was rated "poor". Our regimen of controlled motion rehabilitation has also been applied with equal success to cases of flexor tendon grafting.

In 1981, we adopted a combined regimen of controlled motion following repair of flexor tendons of the hand. It incorporated features from the technique of controlled active extension against passive flexion produced by a rubber band (Kleinert et al. 1967; Lister et al. 1977), and those of controlled passive extension and passive flexion (Duran and Houser 1975; Strickland and Glogovac 1980).

The multi-centre study was performed at the Walter Reed Army Medical Center, Washington; William Beaumont Army Medical Center, El Paso; Brooke Army Medical Center, San Antonio; and the Veterans Administration Medical Center, Washington under the academic auspices of the Armed Forces Medical School, Uniformed Services University of Health Sciences, Bethesda, Maryland.

METHODS AND MATERIALS

Technique of tenorrhaphy. The flexor digitorum profundus tendon was repaired by grasping suture technique (modified Kessler suture or Tajima suture), using 4-0 braided synthetic suture material. This was supplemented by a circumferential running suture of 6-0 Nylon. For repair of the superficialis tendon, horizontal mattress sutures were used. Optical loupes were used for magnification.

No attempts were made to close the flexor tendon sheath, but the anatomical pulleys of the fibro-osseous tunnel were preserved whenever possible.

Postoperative regimen. The rehabilitation programme of controlled motion is divided into three stages, each lasting two weeks (Fig. 1).

During the first four weeks after tenorrhaphy, we utilise the Brooke Army Hospital modification of the rubber band passive flexion splint (Chow et al. 1987) in conjunction with voluntary active extension of the interphalangeal joints (Duran and Houser 1975; Strickland and Glogovac 1980). Our modification of the rubber band traction system, as described by Thomas at the
Second International Meeting of the American Society of Hand Therapists at Boston in 1983, is based on a thermoplastic dorsal splint and includes a “palmar pulley” provided by a safety pin at the distal palmar crease and a nylon fishing line attached to a fingernail hook (Fig. 2). The fishing line runs through the eye of the safety pin to a rubber band anchored at the proximal forearm. This modification increases passive flexion of the interphalangeal joints by pulling the fingertip to the distal palmar crease of the hand. While doing active extension exercises, the patient is instructed to hold the metacarpophalangeal joint in flexion and then to extend fully the interphalangeal joints. In this way, full excursion of the interphalangeal joints is attained while the tendon repair is protected.

During the first two weeks after repair, full passive extension and passive flexion exercises of the proximal (PIP) and distal interphalangeal (DIP) joints are carefully performed daily by the physician or hand therapist to guard against contracture at the interphalangeal joints (Fig. 3). Our adoption of controlled passive extension effectively prevents the development of flexion contracture of the PIP joint which is not uncommon with the use of Kleinert rubber band dynamic splinting (Duran and Houser 1975; Strickland and Glogovac 1980).

By the fourteenth day after repair, most patients can produce full active extension at the PIP and DIP joints with no extension lag. Therefore, passive extension exercise of these joints ends in the second stage of the rehabilitation programme. During the third and fourth weeks after repair, the patient continues the hourly regimen of active extension against the rubber band.

On day 28, rubber band traction is discontinued. During the fifth and sixth weeks (third stage of rehabilitation programme), the patient performs hourly exercises of active flexion followed by passive flexion and active extension. Upon completion of the six-week regimen, the splint is removed. At eight weeks after operation, active flexion with mild resistance is allowed. Bunnell blocking exercises are instituted, if necessary, to improve the range of active flexion of the fingers.

Patients
From January 1982 to June 1986, 66 patients (78 fingers) were treated in our institutions and completed the six-week postoperative rehabilitation programme of controlled motion.

All patients had sustained complete laceration of the flexor profundus and flexor superficialis tendons in “no man’s land”, without associated injuries except for lacerations of the digital nerves. In order to standardise the criteria for inclusion in this study of tenorrhaphy and rehabilitation of “pure” flexor tendon injuries in Zone 2 of the hand, we excluded fingers with phalangeal fractures, joint injuries or significant skin loss (Strickland and Glogovac 1980). Patients ranged from 12 to 70 years of age, with 48 males and 18 females.

Immediate primary tenorrhaphy within eight hours of injury was performed in 32 fingers. Delayed primary repair was carried out in the other 46 fingers. In 52 fingers, repair of both the profundus and the superficialis tendons was performed. In 26 fingers, only the flexor digitorum profundus was repaired. Lacerations of the digital nerves were found in 36 fingers. Microsurgical neureorrhaphy was performed, using 10–0 Nylon.

All patients in the four institutions, under the auspices of the Uniformed Services University School of Medicine, were treated postoperatively by the Washington regimen of controlled motion rehabilitation. The work in all centres was monitored by the same hand therapy consultant to ensure that the protocol was strictly followed.

Evaluation
Two systems were used to evaluate the functional results of the flexor tendon repair.

**Strickland formula (TAM).** The total active motion (TAM) of the PIP and DIP joints is the sum of flexion at the two joints minus the extension lag in both joints (Strickland and Glogovac 1980). This method was regarded by Strickland as the most demanding set of criteria for the evaluation of performance after flexor tendon repair. The following formula determines the percentage of recovery of total active motion:

\[
\frac{\text{Active PIP + DIP flexion} - \text{Extension lag}}{175} \times 100
\]

\[= \% \text{ of normal active PIP and DIP movement}
\]

The results are classified as shown in Table I.

**Louisville system.** The results of flexor tendon function were also assessed on the basis of flexion and extension deficits (Lister et al. 1977). The former is the pulpal-topalm distance; the latter is the sum of extension lag at the metacarpophalangeal and the interphalangeal joints. The criteria of the four categories on this system are: “excellent” – flex within 1 cm of distal palmar crease with less than 15° of extension deficit; “good” – flex

![Diagram of the phases of the six-week rehabilitation programme.](Fig. 1)
Figure 3a - The modified traction splint provides for a greater range of passive flexion of the finger. Figure 3b - Active extension of the PIP and DIP joints; the MP joint is blocked in a flexed position. Figures 3c and 3d - Full passive extension and flexion of PIP and DIP joints performed by the surgeon or hand therapist.
within 1.5 cm of distal palmar crease with less than 30° of extension deficit; “fair” – flex within 3 cm of distal palmar crease with less than 50° of extension deficit; “poor” – pulp-to-palm distance over 3 cm or extension deficits over 50°.

RESULTS

The follow-up of this series of 66 patients (78 fingers) ranges from six months to five years. The results for all patients were independently evaluated by a project coordinator and were documented by video tapes and still photography. Using the Strickland formula for the total active motion (TAM) of the PIP and DIP joints, 62 fingers (80%) were rated “excellent”, 14 fingers (18%) were rated “good”, and two fingers (2%) were rated “fair” (Table II).

<table>
<thead>
<tr>
<th>Group</th>
<th>Total active motion</th>
<th>Percentage of normal movement</th>
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<tr>
<td>Excellent</td>
<td>&gt;150°</td>
<td>85 to 100</td>
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<tr>
<td>Good</td>
<td>125°-149°</td>
<td>70 to 84</td>
</tr>
<tr>
<td>Fair</td>
<td>90°-124°</td>
<td>50 to 69</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt;90°</td>
<td>&lt;50</td>
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Table II. Results of the multi-centre study of 78 flexor tendon repairs in “no man’s land”

<table>
<thead>
<tr>
<th>Method of assessment</th>
<th>Strickland (TAM)</th>
<th>Louisville</th>
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<tbody>
<tr>
<td></td>
<td>Fingers</td>
<td>Per cent</td>
</tr>
<tr>
<td>Excellent</td>
<td>62</td>
<td>80</td>
</tr>
<tr>
<td>Good</td>
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<tr>
<td>Poor</td>
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</tr>
</tbody>
</table>

The same patient as Figure 3, one year after repair of complete laceration of flexor digitorum profundus and superficialis tendons of the index finger in “no man’s land”.

On the Louisville system of pulp-to-palm distance and extension lag, 66 fingers (85%) were rated “excellent”, 10 fingers (13%) were rated “good”, and two were rated “fair” (Table II). There were no poor results by either system.

Rupture of the flexor tendon repair occurred in three patients (three fingers), all due to circumstances unrelated to the regime, and all during the third week after primary repair. Exploration and re-repair of the flexor digitorum profundus tendon was successfully performed in all three cases. Starting again, all three patients completed the six-week supervised rehabilitation programme. The final results were evaluated by both systems; one finger was rated “excellent”, and two fingers were rated “good”. These three digits are included in their respective categories in Table II.

Apart from the three cases of re-repair, no reconstructive flexor tendon surgery (such as tenolysis or tendon grafting) was necessary or performed. In the whole series of flexor tendon repairs in “no man’s land”, the patients returned to work at a mean of three months after operation (Fig. 4).

DISCUSSION

For rehabilitation of the hand after repair of flexor tendons, we advocate a combined regimen of controlled motion utilising both passive flexion by rubber band with active extension and the technique of controlled passive extension and flexion. One major problem of mobilisation by active extension against rubber band traction is the early development of flexion contracture of the interphalangeal joints, particularly the PIP joint, because the patient has failed to achieve full active extension of the finger. A permanent extension deficit often results. The addition of controlled passive extension of the PIP and DIP joints during the first two weeks.
after repair effectively prevents the development of flexion contracture at these two joints.

Our modification of the rubber band traction orthosis provides for a greater range of passive flexion because of the "palmar pulley". This technique accounts for the improved range of active flexion at the end of rehabilitation. The modified dynamic splint can be easily constructed with readily available material – a dorsal splint of thermoplastic material, three Velcro straps, a safety pin, some nylon fishing line and a rubber band. It has been proved to be cost-effective.

We graded our results by the same criteria as Lister et al. (1977) and Strickland and Glogovac (1980). Therefore, it is possible to compare our results with these two classical studies. Because we adopted, combined and improved upon the best features of their rehabilitation programmes it is understandable that our results should be better.

**Application in flexor tendon grafting.** Our regimen of controlled motion rehabilitation has also been used after flexor tendon grafting in the hand, with equal success. These patients were not from our flexor tendon repair study, but were referred to us from other medical facilities for reconstructive surgery. In postoperative treatment after flexor tendon grafting, special attention should be given to controlled passive extension at the DIP joint by the surgeon or hand therapist to prevent flexion contracture at this level. Early controlled movement effectively diminished adhesions in the whole area of the graft and the remaining original tendon.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official, or as reflecting the views of the Department of the Army or the Department of Defense.

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**REFERENCES**


