Splint Modification for Flexor Tendon Repairs

(hand function, hand rehabilitation, occupational therapy, postoperative orthosis)

Mary Sullivan Lopez  Kevin F. Hanley

A modification of the Kleinert orthosis providing early controlled mobilization following flexor tendon repair is presented in the article. Ongoing evaluations of the efficacy of the splint are described and implications for use in treatment are reviewed.

The views expressed in this paper are those of the authors and do not reflect official United States Army or U.S. Department of Defense Policy.

Throughout the history of tendon repair, surgeons, therapists, and patients have been plagued by adhesion formation. In 1948 Pulvertaft noted, “It is not difficult to suture tendons and prepare the ground for sound union. The real problem is to obtain a freely sliding tendon capable of restoring good function.” (1, p 82) One method of dealing with or preventing adhesion formation following tendon repair has been early motion.

The concept of early motion following tendon repair is not new. In 1911 Lexor (2) stated that adhesions could be avoided by mobilization as early as six days after surgical repair. This idea was challenged by Mason and Allen in 1941 (3), who stated that early motion, especially early active, unrestricted motion leads to marked reaction and adhesion formation. They recommended complete im-

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mobilization followed by protective rehabilitation. Since that time, numerous studies have revealed much about the tendon structure, vascularization, and the healing process following tendon repair (4-7).

Based on these studies, Duran and Houser reported, "It would appear from experimental and clinical observations that 3 mm to 5 mm of extension motion of the tendon anastomosis in a passive exercise program is sufficient to prevent firm adherence of a repaired flexor tendon." (8, p 105)

In the first focused study on the benefits of early controlled mobilization, Strickland and Glogovac (9) supported the assumptions of Duran and Houser (8) with statistically significant results.

Kleinert and associates (10) have used a dynamic splint to provide early controlled mobilization. A dorsal plaster splint is applied with the wrist in flexion and the digit at zero degrees. Dynamic rubber-band traction applied to the fingernail holds the digit in flexion but permits active extension to zero degrees (see Figure 1).

Presently, occupational therapists in several Army medical facilities are employing a modification of the Kleinert orthosis in rehabilitation following tendon repair. The modification includes a palmar pulley that allows passive motion of the interphalangeal joints of the digits. The palmar pulley changes the direction of the fingernail traction, pulling the digits into the palm and flexing the interphalangeal joints fully rather than pulling the digits toward the distal forearm and only providing minimal interphalangeal flexion. The purpose of the modification is to maximize flexor tendon excursions through full finger flexion, improve digital function with increased digit mobility, and demonstrate that advancement of the pulley into the palm of the hand does not overstress the repair (11).

Results following use of the splint modification are being compiled and evaluated at Silas B. Hays Army Community Hospital at Ford Ord, California, Brooke Army Medical Center in San Antonio, Texas, and Walter Reed Army Medical Center in Washington, D.C.

The purpose of this article is to describe the modified orthosis and the preliminary positive results following use of the splint.

Procedures

The three Army hospitals follow the same basic postoperative procedure outlined in the following paragraphs.

Following Zone II flexor tendon repair, the hand is placed in a bulky compression dressing, and traction is begun with a dorsal plaster splint positioning the wrist at 20 degrees less than full flexion, the metacarpophalangeal joints at 20 degrees of flexion, and the interphalangeal joints at zero de-
degrees. Following surgery, a proximal pulley (safety pin) may be placed in the palm (11). Within the first three postoperative days, the bulky compression dressing and plaster splint are removed, and a dorsal thermoplastic splint is fabricated.

The thermoplastic dorsal splint is constructed with the wrist maintained at approximately 20 degrees short of full flexion. A metacarpophalangeal stop maintains the metacarpophalangeal joint (MCP) at 20 degrees of flexion. The splint may or may not extend to the fingertips with the interphalangeal joints (IPs) fully extended. Some therapists have stated that this splint continuation over the IPs may prevent flexion contractures by providing sensory feedback when the patient actively extends his or her digits. In our experience at Fort Ord, this continuation did not appear to make a difference in the end result if the therapist could periodically reinforce full active extension. Only the affected digit(s) are included in the splint.

The splint contains a palmar piece with a pulley in the appropriate position for full digit flexion and a forearm piece as a traction base (see Figure 2). The palmar

Figure 2
Modified splint with palmar pulley
piece should fit the metacarpal-
transverse arch accurately and
allow the metacarpophalangeal
joints to flex to 90 degrees. The
splint also should retain the
normal axis of movement. (Note
that the digits normally point to
the navicular when flexed.) The
palmar and forearm pieces may be
constructed from thermoplastic
material or from safety pins and
straps.

A wire foam splint that uses
the same concept of a palmar pulley
with controlled mobilization post-
flexor tendon repair is available
on the market; however, no doc-
dumented research has been found
to support the use of a palmar
pulley. As with all prefabricated
splints, the principal advantages
are in the time and personnel re-
sources saved. However, individu-
ally fitted splints often function
better than prefabricated splints.
In terms of design of the prefab-
ricated splint, some difficulties
with the extended wrist angle, the
location of the palmar bar, and the
interference of the opponens bar
have been noted.

At time of surgery, a 0 to 2-0
nylon monofilament is usually
sutured through the tip of the af-
fected digit's nail. This is the site
for the distal attachment of the
rubber band. A fingernail hook
also works well. The nylon mono-
filament is necessary for smooth
gliding through the palmar pulley.
The rubber band attached to the
monofilament should allow full ac-
tive extension, but should be
strong enough to return the digits
to full flexion. This traction
should be maintained constantly
for the first three weeks.

The following timetable for
Kleinert traction was adapted fol-
lowing the first three weeks in
traction:

1. During the third to fourth
week, the patient is allowed out of
traction during clinic treatment
sessions and allowed active range
of motion (AROM) with no resis-
tance. The dorsal splint remains
on during all nonclinic periods.

2. In the fourth to fifth week,
the patient is allowed light hand
activity, for example, picking up
light objects that are close to the
weight of a checker. The patient
may start gentle flexion of the re-
paired digit over a finger or
thumb.

3. During the fifth to sixth week,
the patient may continue using the
hand in object manipulation and
can begin light activities of daily
living (ADL). Gentle digit flexion
over a finger or thumb is in-
creased, and the patient is allowed
to remove the dorsal splint during
periods of protected activity, for
example, watching television or
light clinic activities.

4. In the sixth to seventh week,
ADL and clinic activities are con-
tinued with the splint removed.
The gentle digit flexion over a
finger or thumb discontinued.
Evaluation of AROM of the
digit(s) and determination of the
splinting needed are required at
this point.

5. After the seventh week, full
use of the hand should be allowed
in all activities except those that
are extremely heavy. If flexion or
extension contractures are present
(for example, proximal interpha-
angeal joint flexion contractures),
it will be necessary to splint. Pa-
ient may be returned to a full
workload.

**Discussion**

Tendon healing has been a topic
of much controversy. Following
his experiments with dogs, Poto-
zena (5) stated that the tendon
heals by cellular activity of the
sheath and surrounding tissue,
and he noted that the tendon is
quite passive in the healing pro-
cess. In 1975, Caplan, Hunter, and
Merklin (7) demonstrated the
presence of an intrinsic vasculari-
ty of tendons. This gave support to
the idea of end-to-end tendon
healing. The findings of Lund-
borg and Rank (4) strongly indi-
cated that tendons possess an in-
trinsic potential for repair if they
receive a nutritional supply suffi-
cient to satisfy the increased de-
mand required for cellular prolif-
eration and collagen synthesis.

The idea of end-to-end healing
was further supported by Becker,
Graham, Cohen, and Diegelmann
(6) who demonstrated that tendon
fibroblasts are active cells able to
proliferate and migrate from the
cut edge of a tendon. With the in-
formation from previous studies,
Matthews and Richards (12) dem-
onstrated intrinsic tendon healing
when a partially divided tendon is
isolated from the sheath incision
or when constant motion is main-
tained.

Occupational therapists are con-
cerned with all aspects of human
function. Hand use is an essential
component of functioning, and
many therapists have developed
special interests in the evaluation
and treatment of hand dysfunc-
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tion. Therapists involved in reha-
bitation following surgical repair
of tendons should familiarize
themselves with the physiological
processes occurring in tendon
healing.

Therapists have the greatest im-
portance on the outcome of the tendon
repair during the postoperative
care period. The idea of con-
trolled mobilization has been sup-
ported and emphasized as impor-
tant in tendon healing in recent lit-

erature. It has been strongly suggested that adhesion formation is reduced or prevented through the use of early controlled mobilization; however, uncontrolled early active flexion may disrupt the tendon repair (13). Mason and Allen (3) demonstrated that early motion may be expected to lead to a rapid increase in tensile strength of the union. Electromyographic studies (13) have demonstrated that contraction against resistance of one group of muscles results in synergistic relaxation of its antagonists. This means that there is a minimum of stress placed on the tendon repair site when controlled mobilization is used. Perhaps the most significant benefit following early controlled mobilization is the speed at which function is recovered (13).

The goal of the ongoing evaluations at the three Army hospitals is to expand the idea of controlled mobilization by improving digital function through tendon excursion in the Kleinert splint with the insertion of a pulley at the level of the palm (11). These evaluations also address the statement by Lister and associates (13) against having the digits flex into the palm, because they felt this might overstress the hand. The results to date have not supported this statement.

Evaluation of results following the use of the splint modification at Fort Ord and Brooke Army Medical Center have been based on the criteria proposed by Kleinert (10) (see Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Criteria for Evaluation of Results</th>
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<tbody>
<tr>
<td>Excellent</td>
<td>Flex within 1 cm of distal palmar crease with less than 15° loss of extension</td>
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<tr>
<td>Good</td>
<td>Flex within 1.5 cm of distal palmar crease with less than 30° loss of extension</td>
</tr>
<tr>
<td>Fair</td>
<td>Flex within 2 to 3 cm of distal palmar crease with more than 30° loss of extension, but less than 50°</td>
</tr>
<tr>
<td>Poor</td>
<td>Greater values of distance to distal palmar crease, extension loss or both, or tendon rupture</td>
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</table>

The splint has been used with ten patients and has produced 87 percent good to excellent results (11). Walter Reed Army Medical Center has used the criteria proposed by Strickland and Glogovac (9) and has reported 100 percent good to excellent results with 22 tendons in 11 digits. Since these samples are limited, further evaluation is needed before a justified conclusion on the efficacy of the splint modification can be reached.

Although a direct comparison cannot be drawn, the demonstrated trends following use of splint modification are encouraging in view of previously reported results. In a sample of 360 cases, Kleinert and associates (10) reported 75 percent good to excellent results. Lister and co-workers 1977 (13) reported 80 percent good or excellent results with a study of 156 severed flexor tendons in 68 patients. Both of these studies used the criteria proposed by Kleinert (10). Strickland and Glogovac (9) reported 72 percent fair to excellent results with a sample of 50 digits in 37 patients; however, their rating criteria were more demanding than the criteria imposed by Kleinert. All previous studies have reported similar final ratings (72 to 80 percent good to excellent) resulting from early controlled mobilization. From the results generated at the three Army hospitals, it appears that the splint modification providing interphalangeal flexion makes a positive difference in the final result of the tendon repair.

Every physician and therapist works for successful outcome of surgical tendon repair. Recent studies agree that the following factors will determine the result of the tendon repair (1, 4, 6, 8-10, 12-14): (1) appropriate surgical technique by a skilled surgeon, including careful suturing to avoid tissue ischemia; (2) released tendon sheath when indicated; (3) early controlled mobilization; and (4) a cooperative patient.

As therapists, we address the need for controlled mobilization and often our postoperative rehabilitative care and ability to enlist the patient’s cooperation in treatment contribute much to the end result. The modified splint described in this article may increase effectiveness in the postoperative care of the patient. Further controlled study is required before the significance of this modification is clearly demonstrated. Also, in-depth analysis of the biomechanics of the modification will clarify the exact impact the splint has on the healing process. With further study, we expect the use of this splint with tendon repairs to be supported, and possibly the idea of the modification can be applied to patients with tendon grafts.

Summary
This report has discussed a modification of the Kleinert orthosis presently in use and has reviewed some of the physiological mechanisms accompanying tendon re-
pair and the use of early controlled mobilization. The hand is an essential tool required for daily functioning and work, which is a key concept in occupational therapy. Early controlled mobilization has demonstrated some definite benefits with more rapid resumption of function. This resumption of function is important to therapists, patients, employers, families, and society-at-large. The preliminary results of ongoing evaluations suggest that use of the modified orthosis produces more effective results and perhaps a better quality functional level in the end.

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REFERENCES