Rehabilitation after Flexor Tendon Repair, Reconstruction, and Tenolysis
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"A man's best friends are his ten fingers" [1]. Complete function and expressive use of one's "best friends" requires an intact flexor tendon system. Much attention and study therefore has been placed over the past several decades in reparation and rehabilitation after a flexor tendon injury. As flexor tendon surgery has advanced through scientific research and clinical investigation, rehabilitation of flexor tendon injuries has progressed right alongside. Immobilization protocols first advocated by Dr. Bunnell [2] evolved into early passive motion protocols, which have evolved most recently into early active motion protocols. The latter, however, has not replaced the former. All three programs still hold their place in hand rehabilitation clinics today. Critical clinical decision-making skills based on knowledge of tendon anatomy, evidenced-based healing concepts, and good communication with the surgeon are required for the hand therapist to guide the person with a repaired flexor tendon system to maximum hand and finger function. The following article reviews the advancement of rehabilitation of flexor tendon repair, reconstruction, and tenolysis.

Flexor tendon primary repair rehabilitation

Immobilization program

Using complete immobilization postoperatively is the most conservative approach to rehabilitation after a flexor tendon repair, and this method still holds a place in hand rehabilitation. “No matter how sophisticated our therapeutic and surgical care becomes, there probably will always be a need for immobilization of flexor tendon repairs in some circumstances” [3]. An immobilization program may be indicated after a flexor tendon repair for the following reasons: children and adults who are unable to comprehend and follow through with a complex mobilization protocol, associated injuries to the adjacent structures, such as fracture, and disorders and health conditions that affect tissue healing, such as rheumatoid arthritis. Collins and Schwarze developed an early progressive resistance program for the immobilized repaired tendon [4]. The immobilization cast or dorsal blocking splint positions the wrist and metacarpophalangeal (MCP) joints in flexion and the interphalangeal (IP) joints in full extension. In general, the cast is removed after 3–4 weeks and is replaced by a dorsal protective splint. The patient begins passive flexion with the wrist held in 10° of extension and gentle differential tendon gliding exercises (Fig. 1).

During this phase, the difference between the digital total active motion and total passive motion is evaluated. A 50° difference indicates dense adhesion formation, which would lead the therapist to initiate early progressive resistance beginning with blocking exercises (Fig. 2).

If at 4.5 weeks extensive adhesions remain, light putty squeezing and putty extension looping is commenced. At 4–6 weeks the dorsal protective splint is discontinued during the day, but the
patient is advised to wear the splint when outdoors and during sleep for protection. Gentle active wrist and digital extension begins, together with blocking and fisting exercises. At this phase, if extrinsic flexor tightness is noted, a forearm-based splint holding the wrist and digits in comfortable maximum extension is worn at night. Typically, significant resistive exercise begins at 6–8 weeks. Timing and load intensity of the resistive exercise depends on the severity of adhesion formation (Table 1).

**Controlled motion programs**

Because of improvements in strong, gap-resistant suture techniques [5], a trend has developed in tendon rehabilitation from immobilization to early controlled motion protocols. Studies have shown that early controlled forces applied to the healing tissues improve recovery of tensile strength [6], decrease adhesions [7], improve tendon excursion [8], and promote intrinsic healing [9]. Controlled motion rehabilitation protocols were developed mainly for zone II flexor tendon repairs but also are used with adaptation for zones I, III, IV, and V. Zone II is the area from the metacarpal head to mid-middle phalanx. The flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) are housed in zone II within a flexor tendon sheath. Repairs in this zone have the highest probability of adhesion development because of its unique anatomy, including Camper’s chiasm, vincular anatomy, and the presence of the A2 and A4 pulleys. For the hand therapist, edema, scar formation, and patient compliance also contribute to the challenge of rehabilitation after a zone II flexor tendon repair.

There are two basic passive motion programs that stand as the basis for other passive motion protocols: the Kleinert method and the Duran method. Both approaches have been adapted, built on, and even combined by hand specialists, including the Washington regimen [10].

**Kleinert program**

In the 1960s, Kleinert and others introduced an early controlled passive motion protocol using a dorsal protective splint (wrist, 30° flexion and
MCP, 30°–40° flexion) with elastic traction from the fingernail to the volar forearm (Fig. 3).

The elastic flexion pull acts as the repaired flexor tendon unit without flexor muscle contraction. Active extension of the digit is performed to the limits of the dorsal blocking splint. Because of flexion contractures at the proximal interphalangeal (PIP) joint and loss of active distal interphalangeal (DIP) motion, two modifications became standard: a palmar pulley was added to improve DIP flexion, and at night the elastic traction is detached and the fingers strapped into extension within the splint to prevent PIP joint flexion contractures. Table 2 outlines the basic Kleinert protocol.

**Duran program**

In the 1970s Duran and Houser [11] introduced a controlled passive motion protocol using a similar dorsal protective splint without elastic traction. The program was designed in response to their measurement that 3–5 mm of tendon glide would prevent restrictive adhesion in zone II. Passive DIP extension with PIP and MCP joint flexion was found to glide the FDP away from the FDS suture sites. Passive PIP joint extension with MCP and DIP flexed glides both tendons away from the injury site. Table 3 outlines the basic Duran protocol.

**Early active motion**

Since the late 1980s and early 1990s early active motion protocols developed in response to experimental and clinical studies that demonstrate beneficial effects of early (as early as 24 hours postoperative) active motion [12,13]. Early active motion protocols depend on strong repair techniques [14]. The force application during rehabilitation must be less than the tensile strength of the repair to prevent gapping or rupture. Combined metacarpophalangeal (MP) flexion and wrist extension has been found to produce the least tension on the repaired site and to allow the most differential excursion between FDS and FDP on a repaired tendon [15,16] Cadaver studies using tenodesis motion showed the following tendon excursions: FDS, 15.2 mm; FDP, 19.8 mm; and FDS-P, 4.6 mm.

Strickland introduced an early active motion protocol (Indiana Hand Center) for a four-strand repair with an epitendinous suture (Table 4) [17]. The Indiana protocol incorporates the tenodesis motion within a hinged splint that allows for 30° of wrist extension. Good patient motivation and comprehension and controlled edema and minimal wound complications are required [18].

There are protocols that incorporate early active motion exercises while using a Kleinert protocol.
type dorsal blocking splint. Evans developed a program for the repair with a conventional modified Kessler and epitendinous suture with a two-strand core [19]. The program includes a dorsal blocking splint with wrist in 30° flexion, MCP joints in 45° flexion, and IP joints in full extension. The splint includes four-finger elastic traction with palmar pulley during the day and full IP extension at night. The active motion component of the program is performed only with therapist participation, until 3 weeks, when the patient is permitted to perform them without supervision. For zone I repairs, Evans includes a second dorsal digital splint extending the length of P2 and P3 maintaining the DIP joint in 40°–45° of flexion with no dynamic traction [20].

Silfversköld and May designed a program for a modified Kessler repair and epitendinous circumferential cross-stitch [21]. The dorsal blocking splint holds the wrist in neutral, MCP joints at 50°–70° flexion, and the IP joints in full extension. All fingertips have elastic traction through a palmar pulley. Active extension/passive flexion with elastic traction and passive flexion to the distal palmar crease are performed 10 times hourly. During passive flexion, light active muscle contraction is allowed for 2–3 seconds. Active motion is performed only under therapy or surgeon supervision for the first 4 weeks. At 4 weeks the splint is removed and unassisted active flexion and extension are initiated. Gentle resistive flexion begins at 6 weeks, and at 8 weeks progressive resistive exercises begin.

Even with the advances of early motion rehabilitation programs after a primary flexor tendon repair, getting good to excellent results in active functional PIP and DIP joint motion remains a clinical challenge for hand therapy clinicians. Each patient with a repaired flexor tendon presents a unique set of challenges requiring an individualized approach to rehabilitation. Karen Pettengill promotes that institution of and progression to an active mobilization program depends on the extent of injury, repair technique, patient compliance, patient general health, and tendon response. In general, if good tendon excursion is achieved quickly, “keep the brakes on”; if poor tendon excursion,
Table 4
Early active motion program (Strickland/Indiana Hand Center)

<table>
<thead>
<tr>
<th>0–3 days</th>
<th>0–4 weeks</th>
<th>4 weeks</th>
<th>5 weeks</th>
<th>6 weeks</th>
<th>8 weeks</th>
<th>14 weeks</th>
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<tbody>
<tr>
<td>Dorsal blocking splint with wrist in 20° flexion, MCP joints in 50° flexion</td>
<td>Duran passive motion performed 15 times every 2 hours</td>
<td>Dorsal blocking splint removed during exercise but continued for protection</td>
<td>Active IP flexion with MCP extension followed by full digital extension</td>
<td>Blocking exercises begin if active tip to distal palmar crease is more than 3 cm</td>
<td>Passive extension can begin at 7 weeks</td>
<td>Progressive resistive exercises initiated</td>
</tr>
<tr>
<td>Tenodesis splint allowing 30° wrist extension and full wrist flexion, maintaining MCP joints in 50° flexion (a single hinge splint with a detachable extension block can also be used)</td>
<td>Tenodesis exercises within hinged splint 15 times every 2 hours</td>
<td>Tenodesis exercises continue Instruction to avoid simultaneous wrist and finger extension</td>
<td>Central tendon exercises within hinged splint 15 times every 2 hours</td>
<td>Progressive resistive exercises initiated</td>
<td>Unrestricted use of hand</td>
<td>Unrestricted use of hand</td>
</tr>
</tbody>
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“accelerate!” (Karen M. Pettengill, MS, OTR/L, CHT, personal communication, May 2004).

Instead of advocating a “sweeping postoperative regimen or protocol without allowances for individual physiologic tissue or biological responses,” Groth [22] proposes a methodic rehabilitation model that progresses the patient based on force application and individual tissue response through her thorough literature review. Groth’s “pyramid of progressive force application” places the exercise with the lowest level of force on the bottom, with a total of eight progressions to the top of the pyramid where the load is the highest. The bottom five levels are with wrist protection, the top three without. The progression from lowest to highest is as follows: passive protected digital extension, place and hold finger flexion, active composite fist, hook and straight fist, isolated joint motion, resistive composite fist, resistive hook and straight fist, resistive isolated joint motion. Groth details internal tendon loads, tendon excursion amounts, and clinical application information for each of the progressive levels. A flexion lag grade becomes the basis for systematic and tailored application of motion stress to the repaired tendon. Adhesions are absent if less than or equal to a 5° discrepancy exist between active and passive flexion. Adhesions are responsive if there is greater than or equal to a 10% resolution of lag between therapy sessions. And adhesions are considered unresponsive if there is less than or equal to 10% resolution of active lag between therapy sessions. If the flexion lag is determined to be unresponsive, the load application increases one level up the pyramid. For example, active composite fist exercises might begin as early as week 2 if the active lag is determined to be unresponsive. If a lag never occurs, this exercise is delayed until 8 weeks post-surgery. Groth’s model can be used with any existing protocol and is not limited to zone, type of suture repair, or time sequence. Groth cites two case studies based on her model; both of the patients were discharged with excellent results based on Strickland’s formula and classification system.

Clinical problem solving is of utmost importance for the hand therapy clinician in progressing a patient with a primary flexor tendon repair [18]. The future of good to excellent functional outcomes through rehabilitation after a primary repair to the flexor tendon system is based on science and art. Functional outcomes do not depend on following a prescribed protocol, but on progressing each patient individually with the available evidence-based information and on observation of the individual’s healing response. More experimental research and clinical outcome studies are critical to the continued advancement of rehabilitation after a primary flexor tendon repair. Through experimental cadaver studies, Mass has concluded that using a locked cruciate four-strand repair is as strong as the modified Becker repair (>60 N), has a lower work of flexion, and is easier to perform [23]. Clinical studies to determine functional outcomes after such repairs are underway to support his findings. Appropriate patients begin immediate early active gentle fisting with therapist supervision with the wrist positioned in neutral to −30° extension and MP joint extension limited to 60° flexion (Fig. 4).

Rehabilitation after flexor tendon reconstruction

When a primary repair of the flexor tendons is not an option, staged tendon reconstruction becomes the treatment of choice. The following outlines rehabilitation after flexor tendon reconstruction using passive and active tendon implants.

Passive tendon implant

Stage 1

Therapy goals during stage 1 are maximum passive motion, correction of flexion contractures, and a viable gliding bed. A dorsal protective splint is worn for 3 weeks with wrist positioned in 30° flexion, MCP joints flexed to 60°, and splint extending 2 cm beyond the fingertips. Gentle passive flexion/active extension and light finger
trapping, 10 repetitions each, 4 times a day are initiated the first week. PIP joint flexion contractures must be addressed immediately with a dorsal digital extension splint within the dorsal protective splint. Synovitis must be avoided carefully through instructing the patient not to be overly aggressive. At 3 weeks the dorsal blocking splint is discontinued and buddy taping begins.

Stage II

A dorsal blocking splint with identical positioning as the stage I splint is applied. Full IP joint extension must be allowed within the splint. Gentle passive flexion of each IP joint is performed hourly. At 4 weeks the dorsal protective splint is replaced by a wrist cuff with elastic traction. The traction should allow full IP joint extension with the wrist in neutral. At rest the repaired finger is maintained in flexion. The wrist cuff is removed at 6 weeks and light activity is allowed. Blocking and tendon-gliding exercises are initiated. Contracture control continues. At 8 weeks, progressive strengthening exercises begin.

Early protected active motion can be considered if the tendon graft is fixed with strong techniques, the gliding bed is in good post-surgical condition, and the patient is known to be motivated and compliant.

Active tendon implant

Stage I

Therapy begins the day after surgery with a dorsal blocking splint and passive flexion exercises. At 2 weeks elastic traction is added. If pulleys were reconstructed, they must be protected using a pulley ring made from thermoplastic material or Velcro, and during flexion exercises the patient must apply pressure to support the pulley. IP flexion contracture control begins the first postoperative week. Soft foam squeezing begins at week 3 and light putty squeezing after 4 weeks. At week 6 the dorsal protective splint is replaced with the wrist cuff with elastic traction. By 8 weeks progressive strengthening begins.

Stage II

After removal of the tendon implant and insertion of the tendon graft, the same dorsal blocking splint is applied. Early motion with elastic traction begins on day 1. Ten repetitions every waking hour of passive flexion/active digital extension are performed by the patient. Gentle passive flexion is performed 10 times, several times a day. Therapy is similar to after stage I; however, because early pain-free gliding usually occurs, the progression of the program may have to be slowed to protect the tendon junctures [24].

Rehabilitation after tenolysis

Tenolysis, the surgical release of adherent tendons, is indicated for patients whose post-repair progress has plateaued with a significant difference between passive and active range of motion measurements. Tenolysis is considered only if a patient is highly motivated and presents with soft and supple tissues, good passive range of motion, and good strength [25]. Thorough

Box 1. Tenolysis program

- Edema control: within 24 hours, bulky dressing removed and light compressive dressing applied.
- Active and passive extrinsic stretching: active wrist and digital flexion followed by active wrist and digital extension for maximum FDS and FDP excursion, every waking hour.
- Active and passive tendon gliding: composite fist, hook fist, full digital extension for maximum differential tendon glide between FDS and FDP (Fig. 5) every waking hour.
- Blocking exercises: independent blocking at the PIP joint and DIP joint for maximum mechanical advantage of tendon pull-through, every waking hour.
- Isolated PIP joint blocking: for independent contraction of FDS without motor help from FDP, every waking hour (Fig. 6).
- Splinting: static extension splinting between exercises and at night recommended.
- Progressive resistance exercises: begins at approximately 6 weeks postoperatively.
- Wound and scar management throughout rehabilitation process.
- Adjunct therapy: modalities including neuromuscular electrical stimulation (NMES), ultrasound, and so on.
information must be obtained from the surgeon at the time of referral, including the active and passive range of motion achieved during surgery, vascularity, any additional procedures that might have been done, and prognosis. Rehabilitation depends on poor or good tendon integrity based on the referral information obtained. Tendons of poor integrity have an increased likelihood of rupture and require protective splinting and a controlled range of motion program. Cannon and Strickland advocate a frayed exercise program that includes place and hold exercises that place less tensile loading on the lysed tendon than active range of motion [26]. Tendons of good integrity begin therapy immediately, summarized as follows (Box 1) [27].

Summary

Flexor tendon rehabilitation after injury and surgical intervention has progressed over the last several decades. This evolution has left a vast amount of information for the hand therapy clinician. The hand therapist treating a primary flexor tendon repair can easily feel daunted, confused, and apprehensive because of the sheer amount of information before him or her, which may lead to patient treatment with a textbook or cookbook approach. This article outlines the history of flexor tendon programs and their evidenced-based development so that the clinician can approach each patient individually and progress them with a personalized, tailored approach in close communication with the surgeon. Successful flexor tendon rehabilitation’s end-result is functional hand motion and strength. As experimental studies on improved surgical techniques continue to develop, more clinical research to support rehabilitation techniques that lead to good hand function results are necessary.

References


