Management of Flexor Tendon Injuries following Surgical Repair

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Remarkable strides have been made in the treatment of flexor tendon injuries in the past 40 years. Advances in the understanding of flexor tendon anatomy, nutrition, healing, and biomechanics has significantly improved the treatment of these challenging injuries. Many advances also have been made due to the cooperation between the hand surgeon and the therapist. This coordinated effort has resulted in improved postoperative treatment programs following flexor tendon repairs.

Prior to the 1970s, repair of intrasynovial flexor tendon injuries yielded consistently poor results. Bunnell named this region of the hand, “No man’s land.” Later studies showed that a strong repair coupled with early motion yielded excellent results. Primary tendon healing, without the in-growth of adhesions, has been demonstrated both clinically and experimentally.

Effects of Motion on Tendon Healing

Since the work of Mason and Allen, in the 1940s, the benefits of early mobilization and low levels of stress applied to tendon repairs have been realized. In their study, Mason and Allen noted that early motion created a stronger repair in wrist flexor tendons using a canine model. When protected mobilization was incorporated, the tensile strength of the tendon repair increased after the seventh postoperative day. Along with this work, Birdsell and colleagues showed the effect of tendon immobilization on the tenocyte. The relatively inactive, mature tenocyte had decreased activity with immobilization.

In the early 1980s, Gelberman and various associates reported on the effects of early mobilization on tendon healing in canines and swine. Using microangiographic techniques applied to freshly amputated limbs, they demonstrated the responsiveness of the tendons’ extrinsic vascularity to early protected mobilization. Increasing the range of passive motion was associated with improved scar characteristics when compared to immobilized tendons. In 1981, Gelberman and his group used a canine model to show the positive biomechanical effects of controlled passive motion on tendon repair. Approximately 12 weeks following tendon repair, those tendons subjected to motion regained over one-third of their tensile strength compared to the intact controls. Also, gliding function of the tendons subjected to controlled passive motion was significantly better than for those tendons in the continuous immobilization group. Using the same model of canine flexor tendon healing in several investigations, Gelberman and coworkers looked at the effect of early mobilization on tendon healing. The tendons in the early mobilization animal models showed progressively greater ultimate loads-to-failure at all time points tested. The mean load-to-failure of the early mobilization groups at 3 weeks was twice that of the immobilized cohort at the same time interval. Investigators of the latest publication of this group of studies concluded that “early passive motion augments the physiologic processes that determine the integrity and excursion of repaired flexor tendons.” With these series of studies, Gelberman and colleagues also showed that immobilized tendons heal by both extrinsic and intrinsic means. The in-growth of connective tissue from the flexor tendon sheath resulted in extrinsic healing. Tenocytes within the tendon contributed to intrinsic healing. Tendons subjected to early mobilization healed only...
by intrinsic means without adhesion formation.

**Postoperative Management**

Current protocols for postoperative management for patients with flexor tendon injuries include: immobilization, early passive mobilization, and early active mobilization. Stewart and Van Strien presented a comprehensive review of these different protocols.15

**Immobilization**

The prerequisite for an early passive or early active mobilization program is a motivated patient with the ability to understand the exercises and the precautions involved. Immobilization is indicated for patients who are unable or are unwilling to adhere strictly to the early mobilization protocols. This group includes children under the age of ten, as well as patients with cognitive deficits.15 These patients benefit from the protection of the repair site with immobilization until adequate healing has taken place. Immobilization is also indicated for patients with injuries to other structures potentially damaged by early mobilization (i.e., repaired or healing fractures, nerves, and vessels).

Studies of immobilization after flexor tendon repairs are performed in children due to their inability or difficulty to comply with an early mobilization protocol. Kato and associates looked at the results of zone two flexor tendon repairs performed in children under the age of six.16 All 12 patients underwent repair using a modified Kessler suture and postoperative immobilization with an above-elbow cast. No ruptures were reported; however, one finger required tenolysis. The mean total active motion of the IP joints averaged 89% of the uninjured fingers. Using the Strickland and Glogovac criteria, 11 patients had an excellent result and one had a good result. O’Connell and coworkers reported on 95 flexor tendon repairs in 78 patients; all patients were 16 years or younger.17 This study showed that immobilization for longer than 4 weeks resulted in inferior outcomes.

The protocol of Cifaldi Collins and Schwarze involved 3 to 4 weeks of postoperative immobilization followed by an aggressive therapy program.18 The early stage of this rehabilitation program ranged from 3 weeks to 4 weeks postoperatively. Following the tendon repair, a forearm-based dorsal splint or a cast was applied. In children, consideration was given to the use of a long-arm cast. The wrist was held in approximately 20° of flexion, the metacarpophalangeal (MP) joints in approximately 50° of flexion, and the interphalangeal (IP) joints in full extension.

The patients began immediate postoperative range of motion (ROM) exercises of all uninjured joints, including the elbow and the shoulder. The splint or cast was worn 24 hours a day and was removed under the supervision of a therapist once a week for protected passive ROM exercises. Protected passive ROM involved the therapist holding all adjacent joints in flexion while flexing and extending each joint individually. The therapist also may clean the patient’s skin when the splint is removed for therapy. After suture removal, scar massage can help prevent skin and tendon adhesions. Integration of edema control measures involved the use of elastomer or other pressure dressings.

The intermediate stage of therapy began 3 weeks to 4 weeks postoperatively. The splint was modified to bring the wrist to a neutral position. The patient was instructed to remove the splint every hour while awake to perform exercises. The wrist was placed in 10° extension, and the patient performed passive digital flexion and extension for 10 repetitions using the opposite hand. This was followed by 10 repetitions of active, differential tendon gliding exercises. The purpose of these exercises was to permit maximal total and differential flexor tendon glide, based on studies by Welbe and Hunter.19,20 Four days after commencing this phase of therapy, the patient was evaluated for passive and active flexion of the digit. If there was a discrepancy of more than 50° between active and passive motion arcs, the patient’s rehabilitation was accelerated by advancing to the next phase of therapy. If the discrepancy was less than 50°, the patient continued the intermediate phase until 6 weeks postoperatively.15

At 8 weeks following surgery, sustained grip activities was added to the regimen.18 The resistance of these activities were gradually increased over the next 4 weeks. Heavy resistive exercises were avoided before 12 weeks because of the risk of tendon rupture. The immobilization protocol was predicated upon the therapist and surgeon collaborating to structure a reasonable program of added resistance.

**Early Passive Mobilization**

An early passive motion protocol must be tailored to the individual patient. As discussed earlier, the patient must be cognitively intact and motivated. Early passive mobilization programs have been shown to inhibit adhesion formation,
promote intrinsic healing, and produce a stronger repair.\textsuperscript{10,21,22} These same investigators have demonstrated that this protocol also prevented a decrease in tendon strength associated with immobilization.\textsuperscript{10,21,22}

Several groups have analyzed the early tensile properties of healing flexor tendons and the impact of early mobilization. Using a chicken model, Feehan and Beauchene compared cohorts undergoing early passive motion and immobilization.\textsuperscript{23} Both groups showed a predictable increase in strain, stiffness, and stress during the healing period; furthermore, the rate of change of these values was the same among the groups. The tendons treated with controlled passive motion had significantly greater load, stress, and energy absorbed when compared to immobilized tendons.

Hitchcock and colleagues also used a chicken model to evaluate the healing of the FDP tendon.\textsuperscript{21} This group compared immobilization and immediate constrained motion using a tethering splint. The immobilized tendons showed decreases in strength during the first 20 days following repair; the mobilized tendons showed an immediate and progressive increase in strength throughout the study. This investigation demonstrated that the initial loss of repair strength was preventable with an early mobilization protocol.

Using a canine model, Gelberman and associates determined the effect of early passive mobilization on tendon healing.\textsuperscript{4} Their study involved a comparison of early motion, delayed motion, and immobilization of repaired tendons over a 12-week period. Tendons subjected to early mobilization displayed an increased ultimate load-to-failure. The ultimate load of the group mobilized early was twice that of immobilized tendons after 3 weeks. In addition, the immobilized tendons averaged only 19% of the excursion of the uninjured controls, compared to 95% in the early mobilization group.

Strickland and Golgovac also compared immobilization with early mobilization.\textsuperscript{24} They reported on 50 consecutive digits in 37 patients following flexor tendon repairs. One cohort was treated with 3.5 weeks of immobilization; the other group of patients underwent early passive mobilization using the protocol of Duran and Houser. Four ruptures occurred in the immobilization group, with one rupture in the early mobilization group. The final results for the immobilization group were 12%, good; 28%, fair; and 60%, poor. Results from the early passive group were 35%, excellent; 20%, good; 16%, fair; and 28%, poor. Strickland and Golgovac concluded that early passive mobilization was an effective technique to improve the results of flexor tendon repair.

The results of immediate passive mobilization were reported by Lister and colleagues following 156 flexor tendon repairs in 68 patients.\textsuperscript{25} Patients were examined at 6 weeks and at 18 months after the repair. The results of repairs in zone 2 were good-to-excellent in 75%, compared to 84% in other areas.

Chow and coworkers reported in a multicenter study the application of an early passive mobilization program with the use of a palmar pulley.\textsuperscript{26} Using the Strickland formula of total active motion of the PIP and DIP joints, Chow and colleagues reported 80%, excellent; 18%, good; and 2%, fair results. Three ruptures were reported.

Two of the early passive mobilization protocols utilized are the Duran and Houser\textsuperscript{27,28} and the Kleinert protocol.\textsuperscript{29,30} The basic principles of the two techniques were similar. Both use a dorsal blocking splint that places the wrist and the MP joints in flexion to reduce tension on the flexor tendons. Each technique also employs the use of dynamic traction to allow passive digital flexion with the use of a rubber band or other elastic device.

**Duran and Houser Protocol**

In the Duran and Houser protocol, the postoperative dorsal blocking splint held the MP joints at 50° of flexion and the wrist at 20° of flexion (Fig. 1).\textsuperscript{27,28} At the initial postoperative visit, the physician applied a custom-molded dorsal blocking splint designed to hold the wrist and the hand in the same position. These investigators showed that 3 to 5 mm of tendon excursion was necessary to prevent firm tendon adhesions. The patient was instructed to remove the protective Velcro® straps and perform the following regimen twice daily. Using the opposite hand, the PIP and the DIP joints were brought from full flexion to full extension, with eight repetitions for each joint. Then, the patient performed eight repetitions of composite MP, PIP, and DIP flexion. This protocol continued through the fourth postoperative week.

Approximately 5 weeks following surgery, the patients began active extension exercises.\textsuperscript{27,28} These were performed with the use of a wristband. A rubber band was attached from the tip of the finger to the wristband, providing passive flexion and active extension. During this time, the patient also performed blocking and FDS gliding exercises. The late stage began 8 weeks postoperatively. Progressive strength building was encouraged as aforementioned in the immobilization protocol section.

**Kleinert Protocol**

The Kleinert protocol also employed early passive mobilization following flexor tendon repair.\textsuperscript{29,30} A forearm-based

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**Figure 1** A dorsal splint holding the wrist and metacarpophalangeal joints in flexion.
The dorsal plaster splint was applied immediately following surgery. This splint blocked the wrist and MP articulations with 45° flexion. The IP joints were maintained in neutral alignment throughout the splint. The new splint allowed for passive flexion of the digits and active extension of the digits against dynamic traction using rubber bands to facilitate the traction mechanism. The bands were placed on the volar aspect of the splint and directed toward the distal nail plate from just proximal to the wrist. In one investigation using this protocol, electromyographic studies confirmed the relaxation of the FDP tendon during active extension against the traction forces imparted by the rubber band. Early passive ROM exercises were started within the confines of the dorsal splint. At approximately 1 month following surgery, the patients removed the splint and began active flexion and extension exercises. However, patients continued to wear the dorsal splint during periods of inactivity. About 6 weeks after the surgical repair, the dorsal splint was discontinued, and blocking exercises were started. Two months following the repair, resistive exercises were incorporated. Patients resumed normal activities approximately 3 months following the surgical procedure.

Problems that have arisen with the Kleinert protocol include flexion contractures of the PIP joint. Treatment of contractures has consisted of continued intermittent splinting with the IP joints in neutral position. Several investigators have speculated on the difficulty that patients encounter when attempting to move an injured digit against resistance; however, findings in the literature are inconsistent. Studies have shown that rubber bands displayed increased resistance with finger extension. Modifications of the splint and use of a volar pulley may release some of the tension in the rubber band and alleviate some of the tension forces imparted on the digital tendons.

**Continuous Passive Motion**

Modifications to traditional postoperative protocols have incorporated the use of continuous passive motion (CPM) rehabilitation after flexor tendon repairs. CPM devices allow for joints to move through a predetermined arc of motion. One theoretical advantage of CPM devices is that patients often utilize them for longer periods, providing increased mobilization of the repaired tendon.

A randomized prospective multicenter clinical study evaluated the effects of increased duration and repetition of CPM exercises after flexor tendon repairs. By comparing CPM with a traditional early passive motion protocol, Gelberman and associates showed that patients enrolled in CPM used the machine approximately 75 hours per week with a mean of 12,000 repetitions. Those performing traditional exercises did so for about 4 hours per week, completing approximately 1000 cycles. At a minimum of 6 months follow-up, the group that had undergone CPM was found to have attained significantly greater ROM. Further research evaluating the utility of CPM in postoperative protocols following flexor tendon repair is sparse.

**Early Active Mobilization**

Following a flexor tendon repair, early active mobilization entails active contraction of the repaired muscle. Prospective studies covering the achievements of active mobilization protocols are limited. Published postoperative protocols incorporating early active motion enlisted the use of a dorsal blocking splint and limited active flexion for the first 3 weeks to 6 weeks following tendon repair. Allen and coworkers documented one such early active mobilization protocol. This group prescribed a splint with the wrist held at 30° and the MP joints held at approximately 65°. Rubber band flexion traction was also incorporated. The early stage of this protocol recommended hourly gentle active flexion and extension exercises for 3 weeks postoperatively. After the initial gentle active motion phase, a wrist cuff was used in lieu of the splint, and active ROM of the wrist commenced. The late stage of this protocol was initiated at 5 weeks following surgery, with exercises utilizing progressive resistance. Light activities were included 6 weeks following tendon repair. In their series of seven patients, the investigators found that four achieved good-to-excellent results, yielding findings comparable to those patients who were enlisted in postoperative early passive motion protocols.

Several groups in the United Kingdom published similar early active mobilization protocols. The early stage of the protocol lasts for approximately 1 month following surgery. The postoperative splint extends just distal to the fingertips and maintains the wrist at 20° of flexion and the MP joints at approximately 85° of flexion. This splint also incorporates a radial “wing” that wraps around the thumb to prevent proximal migration of the splint. Exercises performed regularly within the confines of the splint include all digits with repetitive cycles of active extension, active flexion, and full passive flexion. The objectives of the first postoperative week included full active extension, full passive flexion, active flexion of 30° at the PIP joint, and active flexion of 10° at the DIP joint. These protocols also recommended gradual progression with active flexion to reach 90° at the PIP joint and 60° at the DIP joint by 1 month postoperatively. The splint was discontinued about 1 month following surgery, with dynamic extension splints utilized for residual flexion contractures. At the conclusion of splint use, patients started protected, passive IP joint extension, with continuation of the aforementioned ROM exercises.

In a prospective study analyzing this postoperative protocol, Small and colleagues reported on 114 patients who had undergone 138 flexor tendon repairs. Good-to-excellent results were achieved in 77% of digits, fair results in 14%, and poor results in 9%. Eleven digits displayed dehiscence of the
surgical repair requiring immediate revision; 7 of 11 revised repairs resulted in a good-to-excellent surgical outcome having undergone a similar postoperative protocol following the revision surgery. Cullen and associates reported on 34 patients who had undergone 80 tendon repairs and found that results of this postoperative regimen compared favorably with other methods at a mean follow-up of 10 months.\(^\text{38}\) In a more recent evaluation, Gratton surmised that the success of this treatment regimen was multifactorial, in part, due to its simplicity in requiring a single splint application and familiarity with the active and passive motion program.\(^\text{39}\)

Several reports and communications from the Indiana Hand Center prescribed another postoperative program, described as an “active hold” protocol.\(^\text{40}\) Following surgery, the digits were placed in flexion, and patients maintained flexion with gentle contraction. In this protocol, each patient utilized two splints, one for daily wear and one for therapy. For daily wear, patients used a dorsal-blocking splint with the wrist at 20\(^\circ\) of flexion and the MP joints at 50\(^\circ\) of flexion. During therapy, the alternative splint was designed with a hinged wrist that allowed for full wrist flexion and limited wrist extension to 30\(^\circ\). In the splint for therapy, full IP flexion and extension were performed, but the splint limited MP joint extension to 60\(^\circ\). Patients performed hourly exercises in the dorsal-blocking splint, doing 15 repetitions of passive IP motion followed by 25 cycles of “place and hold” digital flexion in the tenodesis splint. Patients actively extended the wrist with concomitant passive digital flexion, maintaining digit flexion for 5 seconds per cycle. This cycle concluded with wrist flexion and digital extension within the aforementioned confines of the splint.

Approximately 1 to 2 months postoperatively, patients discarded the tenodesis splint. At this stage of rehabilitation, patients used the dorsal-blocking splint for all activities except tenodesis exercises. Tenodesis exercises were performed every other hour, with 25 repetitions followed by 25 cycles of active flexion and extension exercise for the wrist and digits. Care was taken to avoid simultaneous extension of the wrist and digits. Approximately 2 months following surgery, patients discontinued use of the dorsal-blocking splint and returned to light activities. There were no activity restrictions approximately 3 months following tendon repair.

Silfverskiöld and May modified a previously established early passive mobilization protocol by incorporating an active hold element to their postoperative protocol.\(^\text{41}\) The investigators recommended a postoperative splint extending to the PIP joints. The splint maintained the wrist in neutral position, with the MP joints in approximately 60\(^\circ\) of flexion. Passive motion exercises allowed the digits to progress to full flexion, and then active contraction maintained flexion for approximately 3 seconds per cycle. Following this group of 46 patients with 55 injured flexor tendons, they found two postoperative ruptures and otherwise very good results with their program of early active and passive flexion.

Evans and Thompson proposed an additional postoperative approach and evaluated the minimal tension required to overcome the resistance of the antagonistic muscle-tendon unit, or the idea of “minimal active muscle-tendon tension.”\(^\text{42}\) In biomechanical studies, they found that flexion forces increased at the end of the flexion range, as well as when digital flexion combined with wrist flexion. The guidelines of the Evans and Thompson protocol delineated that active motion exercises should be performed only with a therapist’s guidance and with a passive motion regimen completed at home. For the active motion exercises, the patient removed the postoperative dorsal-blocking splint. With the wrist passively extended 20\(^\circ\), passive flexion was performed at the MP joint at approximately 80\(^\circ\), the PIP joint at approximately 75\(^\circ\), and the DIP joint at 40\(^\circ\). After passive positioning of the digit, the patient was requested to maintain the position with minimal active contraction. The therapist then measured the force of contraction with a small gauge, and the patient continued finger flexion with a force of 50 g or less. Very often, this program was dependent on patients performing their active exercises in the presence of a therapist.\(^\text{16,42}\)

**Conclusions**

Several protocols have been developed for the management of flexor tendon injuries following surgical repairs. Research driven to delineate the factors contributing to a successful postoperative regimen is ongoing. To date, protocols involving immobilization, early passive mobilization, continuous passive mobilization, and early active mobilization have displayed results of variable success. Regardless of the protocol indicated, the communication between the physician, the therapist, and the patient remain paramount in order to ensure compliance and achieve a good clinical result.

**Disclosure Statement**

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**References**