Tendon injury rehabilitation: a manual of algorithm protocols for therapists

Joni Armstrong
University of North Dakota

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TENDON INJURY REHABILITATION
A Manual of Algorithm Protocols for Therapists

by

Joni Armstrong, OTR, CHT

Advisor: Jan Stube, PhD, OTR/L

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Submitted to the Occupational Therapy Department
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This Scholarly Project Paper, submitted by Joni Armstrong in partial fulfillment of the requirements for the Degree of Master’s of Occupational Therapy from the University of North Dakota, has been read by the Faculty Advisor under whom the work has been done and is hereby approved.

Faculty Advisor

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Throughout the product are many figures of hand exercises and hand splints. All of these drawings are original works done by hand in pencil by Joni Armstrong, the primary author.
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My hand patients I have seen over the years and their constant challenge in problem solving so that I continue to create and learn.

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ABSTRACT

In the field of hand therapy there are a variety of protocols for treatment of patients with tendon injury. Review of the literature indicates that most of these protocols have a good anatomical and physiological basis, which then requires the application of clinical experience to decide which protocols to use when treating patients with hand injury. Experienced hand therapists tend to make observations and adapt protocols accordingly to provide patients with good therapy treatment and therefore achieve excellent treatment outcomes. However, therapists that do not see hand patients on a regular basis and do not have a consult base will tend to follow basic protocols to guide their treatment provision. In doing so, therapy is often not modified as observations are made. The purpose of this scholarly project was to develop tendon rehabilitation protocols in an easy-to-use algorithm format that would provide therapists with the clinical reasoning skills that would allow them to provide not only adequate therapy but excellent therapy and therefore achieve excellent therapy outcomes.

Following an extensive literature review combined with clinical experience, a manual of tendon rehabilitation protocols in an algorithm format was developed utilizing a biomechanical frame of reference. Protocols were organized in a week-to-week format based on the physiology of the tissue healing process, and adaptations to the basic protocols were included based on the author’s clinical observations. Areas of treatment addressed included: wound care / scar control, splinting, exercises, and activities of daily living / work skills. Drawings of splints and exercises were also provided in the protocols.
for ease in patient application. In addition to the protocols, two appendices were also
written containing the fabrication instructions and patterns for all of the splints mentioned
and home program instructions.

Use of a portion of the manual as a teaching tool for occupational therapy students
in an entry-level master’s program indicated that it provided information in a very
concise and organized manner, which allowed time for increased hands-on learning.
Review of portions of the manual by therapists working clinically indicated that it would
be a valuable resource in hand therapy practice. These therapists particularly liked the
drawings and home programs that were made available, as well as the readability and
ease of use. It is hoped that this manual will be used in both clinical and occupational
therapy teaching settings, so that patients can be provided with the best possible care and
achieve the best possible treatment outcomes.
CHAPTER I

INTRODUCTION

Upper extremity tendon rehabilitation has been challenging for the occupational / hand therapist for years, requiring knowledge of complex upper extremity anatomy and biomechanics as well as wound healing and scar formation of the tendons and their surrounding tissues. The primary goal of tendon healing following an injury is that of a strong repair that glides easily through full tendon excursion to accomplish complete range of motion, with strength to return to previous functional work and activity. This is difficult as there are many anatomic structures that surround the muscle tendon units in the small space of the fingers, hand, wrist, and forearm. Tendon injury then, typically involves multiple structures besides the tendon when a tendon is lacerated or evulsed. With healing of these structures, scar is formed and scar adhesions between adjacent structures occur easily in this limited space. Tendon adhesions to bone, skin, pulleys, other tendons, synovial sheaths, or fascia, can cause limitation in tendon excursion to decrease range of motion, strength, and functional hand use. Edema can also limit range of motion and hand function.

Research on tendon repair and post surgical therapy protocol over the past fifty years has shown that motion decreases the degree of adhesion formation. However, excessive stress on the tendon can cause rupture of the tendon repair or gap formation. Gap formation occurs when the tendon pulls apart without complete rupture and the gap fills in with scar tissue. This results in a weaker repair, a tendon that is elongated, or a
tendon that does not glide easily due to an increase in adhesion formation. The rehabilitation following a tendon injury needs to find balance between motion that will provide excursion not limited by adhesions, and a strong tendon repair without gap formation.

As tendon injury and healing primarily focus on kinetics concerning forces and kinematics concerning motion, a medical model with biomechanical approach to treatment will primarily be followed, with variation in the programs particularly in the later phases considering the patients individual occupation, interests, and goals.

The goal of this project is to review the literature and combine it with clinical experience in tendon rehabilitation to establish “user friendly” protocols for flexor and extensor tendon injuries. The tendon protocols will be presented in an algorithm format that guides the reader through the clinical reasoning process to consider all the “what ifs” and guide the therapist in choosing deviations from the initial protocol that will provide patients with an individualized therapy program to accomplish the best therapy result. The protocol manual will include picture anatomy descriptions of each tendon zone, so that therapists will, at a glance, know the other structures affected with lacerations in the different zones and the biomechanical changes that will occur with injury to these structures. Pictures of splints and exercises used will also be included in the protocol with instructions and patterns available in the appendix for splint fabrication as well as exercise home programs. With use of this “user friendly” protocol manual, therapists (even those that are new to the field or do not see hands on a frequent basis) will be able to provide patients with the individualized treatment that they need to attain the best tendon function and the best functional hand use following treatment.
The following chapters will include a review of the research available on tendon injury, repair, healing, and therapy treatment, consideration of clinical experience in relation to this research, and application to the development of the algorithm protocols. Use of the protocol manual as a teaching tool with occupational therapy students studying hand rehabilitation and splinting was also considered in its development. Trials were completed using the preliminary protocols with student classes, with many expressing an appreciation of the ease in learning and application to patient treatment. The protocol manual with appendixes will follow with recommendations for implementation of manual use as a clinical tool for therapists as well as in a classroom teaching setting.
CHAPTER II
LITERATURE REVIEW

Tendon Healing

Tendon rehabilitation has evolved dramatically from strict immobilization to immediate active motion protocols, with a variety of treatment and rehabilitation approaches currently being used. Most of the treatment guidelines available reference the importance of a therapist’s understanding of anatomy, physiology, biomechanics, and wound healing not only of the tendons but the adjacent structures. Experienced therapists vary their treatment approach by combining their knowledge and experience with observations of patient healing and function.

Bunnel’s research (1922) on tendon repairs stated the importance of surgical technique and stronger sutures, as well as addressing friction and resistance to tendon gliding and the importance of tendon motion in post-operative exercises, the same basis and questions that most of the more recent research continues to address today. Early studies in tendon healing (Peacock, 1965; Potenza, 1962, 1963) set the stage for further research in and clinical use of protocols involving increased and early motion. These studies and subsequent studies (Abrahamson, Lundborg, & Lohmander 1989; Gelberman, et al, 1991; Lundborg, 1976; Lundborg, Rank, & Heinau, 1985; Manske, & Lesker, 1985; Manske, 1988) discussed the methods of tendon healing as extrinsic and intrinsic. Extrinsic healing involves the formation of adhesions between the tendons and their adjacent tissues, which provide blood supply and fibroblasts for tendon healing. Intrinsic
healing depends on nutrition provided by the synovial fluid, fibroblasts being provided by
the epitenon and endotenon. Extrinsic healing results in adhesion formation which limits
tendon glide and functional motion, while with intrinsic healing motion is not limited.

Tendon is a strong cord of tissue that connects muscle and bone. With muscle
contraction, the pull on the tendon then provides joint movement. Histologically it is
made up of collagen bundles, with small amounts of proteoglycans and elastic fibers.
When a tendon heals, it proceeds, like all tissues, through the 3 phases of wound healing:
inflammatory, fibroplasia, and maturation phases. In the initial inflammatory phase (3 to
5 days), there is an influx of leukocytes and macrophages which stimulate growth and
migration of fibroblasts. The tensile strength of the tendon in the inflammatory phase if
immobilized diminishes and there is softening of the tendon ends. During the fibroplastic
phase (2 to 21 days) fibroblasts migrate to the wound area and start to produce
tropocollagen, which has little tensile strength until the hydrogen bonds of its triple helix
formation are replaced by stronger cross links creating collagen fibers. The collagen
molecules are laid down in a haphazard fashion. This creates a bond between all tissues
in the area. During the maturation (or remodeling) phase (3 weeks to 6 months, or even a
year), the scar remodels through production and lysis of collagen fibers. The randomly
oriented fibers if placed under stress are slowly replaced by newly formed collagen which
is oriented along the axis of the tendon increasing its tensile strength. The collagen fibers
which make up the scar between the tendons and other tissues must become lengthened
and changed to allow for free gliding tendon motion (Brand, 1984).

There are many factors that affect tendon healing following repair (Stewart
Pettengill, & van Strien, 2002), which need to be considered when planning and
progressing patient treatment following tendon repair. Blood supply to the tendon, particularly the number of vincula, decreases with age, so as a person gets older there is a decrease in healing potential. People in good general health, with good exercise and dietary habits, generally demonstrate good healing. Those that have a chronic diagnosis such as diabetes, arthritis, or heart disease, may experience delays in healing. Delayed healing is also experienced in those who smoke tobacco products or consume large amounts of caffeinated drinks such as coffee (vanAdrichem, et al, 1992), due to their effect on circulation. There is individual variability in scar formation as some patients form heavy scar rapidly, and others form minimal scar slowly (Stewart Pentengill & van Strien, 2002). Those who form minimal scar tissue do not have as strong a tendon healing early on and are in greater danger of tendon rupture, where those who form a great deal of heavy scar tissue tend to have tendon adhesion which limits tendon excursion (Gelberman, et al, 1985). Patient motivation, cooperation, and understanding are extremely important factors in tendon healing, as it is necessary for patients to be able and willing to comply with splint use and home program to achieve good tendon healing and motion (Stewart Pentengill & van Strien, 2002). The injury itself and the surgery are also factors that affect the results of tendon healing (Stewart Pentengill & van Strien, 2002). Sharp injuries, that have minimal damage to the surrounding tissues, facilitate a good surgical repair and will generally heal with minimal scar tissue. Injuries such as a crush cause more damage to the surrounding tissues (i.e., bone, pulleys, nerve, vascular) and typically involve more scarring and require different treatment approaches (i.e., increased flexion to decrease tension on a repaired nerve) which may not maximize tendon healing or tendon glide. Tendons cut with a rough instrument, such as a chainsaw
or table saw, may have frayed ends that do not have a healthy base for repair or they may demonstrate some tendon shortening, which places increased tension on the repair site. The amount of tendon retraction can also be a factor, as repairs of a significantly retracted tendon require more surgical intervention to retrieve the tendon and guide it distally for the repair, therefore resulting in potential for increased scar adhesion along the tendon. If there is a delay in the tendon repair, the musculotendonous unit may have shortened placing extra tension on the repair or the tendon ends may have scarred down requiring dissection prior to repair. If the laceration was cut by something that was quite dirty, or the hand was cut while soiled, the wound needs to be carefully monitored for infection during the healing process, and careful debriding, washing, and use of topical or oral antibiotics considered. The zone in which a tendon laceration occurs also affects the tendon healing due to other structures that might be involved and the degree of vascularity to the tissues in a given area, as well as the amount of excursion that typically occurs in that area (Stewart Pettengill, van Strien, 2002).

Tendon Anatomy

The extrinsic tendons originate with muscles in the forearm. There are three extrinsic muscles that function as finger flexors originating from the medial epicondyle and mid-forearm, and four extrinsic muscles that function as finger extensors originating from the lateral epicondyle and mid-forearm. There are also intrinsic muscles that assist in finger flexion and extension as well as three wrist flexors and three wrist extensors. (Gray, 1977; McMinn & Huthcings, 1997; Poritsky, 2000)

Finger flexion is primarily an extrinsic function with help from the lumbricals at the metacarpophalangeal joint (MP) level, primarily involving 3 muscle tendon units
(Britton, & Kleinert, 1996) The flexor digitorum profundus is a deep muscle innervated by the ulnar and anterior interosseous nerves. A common tendon comes off the muscle and then divides at the carpal tunnel into individual tendons. These travel through a sheath as they enter the fingers. Lumbrical muscles originate from the profundus tendon just distal to the carpal tunnel. The flexor digitorum profundus (FDP) lies deep to the superficialis tendon until it bifurcates allowing the profundus to pass through at Camper’s chiasm, then inserting on the volar proximal portion of the distal phalanx. The flexor digitorum superficialis (FDS) is a superficial muscle innervated by the median nerve. This muscle lies superficial to the FDP on the volar side of the forearm. It forms the four superficialis tendons in the distal forearm. As they pass through the carpal tunnel, the tendons to the long and ring fingers are positioned superficial to the index and small fingers. Each tendon enters its appropriate digital sheath, and then divides to allow the FDP to pass through and inserts on the volar sides of the middle phalanx. The wrist flexors also originate from the region of the medial epicondyle, with the flexor carpi radialis inserting at the base of the 2nd and 3rd metacarpals, the flexor carpi ulnaris inserting on the pisiform and the 5th metacarpal, and the palmaris longus (frequently not present) inserting at the base of the palmar fascia. The flexor pollicis longus originates high in the forearm and passes into the radial side of the carpal tunnel. It enters the sheath as it enters the thumb and inserts on the volar proximal end of the distal phalanx (Gray, 1977; & Strickland, 2005). The tendons in the hand are held next to the bones by a series of eight pulleys that lie over the synovial sheaths. They consist of five annular pulleys, which are thick transverse bands, and three cruciate pulleys, which are more flexible crisscrossing fibers (Culp & Taras, 2002). Due to their width and placement, the A2 and
A4 pulleys are the most important in assuring that the tendon maintains a biomechanical position next to the bone preventing bow stringing of the tendon (Idler, 1985). The thumb has only three pulleys, one oblique and two annular, to maintain tendon position in this two joint system (Culp & Taras, 2002).

Finger extension is controlled by a combination of extrinsic and intrinsic muscles (Minamikawa, 1996). The primary extensor is the extensor digitorum communis (EDC). There is a second long extensor to the index finger, the extensor indicis proprius (EDP), and also to the small finger, the extensor digitorum quinti (EDQ). All three if these muscles originate from the lateral epicondyle and insert into the base of the middle phalanx, and function primarily to extend the fingers at the MP level (or at the proximal interphalangeal joint (PIP), if the MP is maintained in flexion). They pass through fibrous tunnels within individual sheaths at the dorsal wrist along with the wrist and thumb extensors. The first tunnel contains the extensor pollicis brevis (EPB) and the abductor pollicis longus (APL). The second contains the extensor carpi radialis longus and brevis (ECRL & ECRB). The third contains the extensor pollicis longus (EPL), and the fourth contains the extensor digitorum communis (EDC) to the four fingers with the extensor indicis proprius positioned underneath. The fifth contains the extensor digit quinti, and the sixth the extensor carpi ulnaris. The wrist extensors with ECRL insertion at the base of the 2nd metacarpal, ECRB insertion at the base of the 3rd metacarpal, and ECU insertion at the base of the 5th metacarpal, are very strong muscles which not only extend the wrist but stabilize it during grasp. There are two thumb extensors, the extensor pollicis longus (EPL), which inserts on the proximal end of the distal phalanx, and the extensor pollicis brevis (EPB) which inserts on the proximal end of the proximal phalanx.
The tendons of the EDC proceed up the dorsum of the hand and are interconnected by the juncturae tendinum which typically runs distally from the ring finger tendon to the little and middle finger tendons and possibly from the middle finger EDC tendon to the index finger tendon. It provides force distribution, coordination of extension, and MP stabilization, but also limits independent extension of the ring finger. As the long extensor tendons proceed into the fingers, they are held in place by the sagittal bands which center the tendon over the MP joint, and then attach at the proximal phalanx as the central slip. The lumbricals and interossei form the lateral slip and then in the conjoined lateral band to form the terminal extensor which attaches at the proximal end of the distal phalanx (Rosenthal, 2002).

The lumbricals which primarily function to flex the metacarpal phalangeal joints of the fingers and extend the PIP joints, originate from the profundus tendons distal to the carpal tunnel and insert into the tendonous expansion of the extensor digitorum communis on the dorsum of each finger. The dorsal interossei originate from the side of the metacarpal and insert into the base of the proximal phalanx and the common extensor tendon. They function primarily as finger abductors. The palmar interossei originate from the palmar side of the metacarpals and insert into the side of the base of the proximal phalanx and the common extensor tendon of the same finger. They function primarily as finger adductors (Gray, 1977).

Tendon anatomy is divided into tendon zones. These zones were established by the International Federation of Societies for Surgery of the Hand (Kleinert, Schepel, & Gill, 1981) and evolved from work by Verdan in 1964. There are five flexor tendon zones, plus the three zones of the thumb. There are eight extensor tendon zones, plus five
for the thumb. They are used to guide surgical and rehabilitation management of tendon injuries.

Tendon Rehabilitation

The goal of tendon rehabilitation is to obtain a strong tendon repair that glides easily through full tendon excursion to achieve complete range of motion and the strength and ability for full functional use. Research over the past 20 years has shown strong support of early motion to promote tendon healing and decrease adhesion formation to facilitate tendon glide and function, however, this has been done through a variety of protocols.

Flexor Tendon Rehabilitation

Articles by Strickland (2005) and Amadio (2005) discuss the importance of surgical repair technique and suture strength in allowing use of early active motion following tendon repair. Amadio reported that the breaking strength of a non-injured tendon can exceed 1,000 newtons (N). A two-strand repair with a 4-0 core suture, which has been the most typically used repair technique until recent years, has a breaking strength of 20 to 30 N, or would withstand a load of 5 or 6 pounds. Larger core sutures (3-0 instead of 4-0), locking loops at the suture corners, and multiple strands (four, six, or eight), increase the strength of the repair to as much as 70 N. Although significantly increased, it is still minimal compared to normal tendon strength. Larger, smoother suture, and buried locking loops, also minimize friction, which can cause increased adhesions or gap formation. Amadio also emphasized that the “safe zone” of tendon motion is dynamic and changes as the tendon heals. Strickland listed the characteristics of an ideal flexor tendon repair to include: secure suture knots, smooth tendon end juncture,
minimal gapping, minimal interference with tendon vascularity, and sufficient strength to allow early motion stress. Research by Komanduri, Phillips, & Mass (1996), Savage & Ristano (1989), and Shaieb & Singer (1997), indicated that the strength of a flexor tendon repair is proportional to the number of core suture strands that cross the repair. Strickland also pointed out that the more suture strands that cross the repair, the more difficult the technique is surgically and the more likely it is to cause excessive damage to the tendon and compromise its nutrition and ability to heal. In addition, excess suture may cause excess friction increasing adhesion formation and decreasing tendon glide. With improvements in suture technique, particularly increasing suture strength by increasing the core number of sutures, there has been an increased move toward using early motion in the follow-up rehabilitation.

The literature refers to three treatment approaches with variable protocols in each for flexor tendon rehabilitation: immobilization, early passive motion, and early active motion (Stewart Pettengill & van Strien, G., 2002). Most of these protocols follow specific guidelines based on the timing of the wound healing process. The main difference in these protocols is in the treatment during the early stage (initial 3 to 4 weeks) following tendon repair.

Although the current research recommends early motion, in situations where a patient lacks the motivation or is unable to understand tendon precautions, home program exercises, and splint use (i.e., young children or individuals who are cognitively impaired) or where there may be delayed healing, an immobilization program is warranted, as the risks of rupture outweigh the benefits of mobilization. An immobilization protocol may also be necessary to protect other structures injured.
Current protocols following immobilization are primarily based on the work of Cifaldi-Collins, and Schwartz (1991). This protocol is outlined in the American Society of Hand Therapists Flexor Tendon Practice Guidelines (1997). In the early stage of tendon healing (0 to 3 weeks), a dorsal forearm based splint in the position of 10° to 30° wrist flexion, and 40° to 60° MP flexion (can be varied depending on zone and associated injuries, but total degrees of flexion should be at least 70°.) with IPs in full extension is applied and worn 24 hours a day. It is only removed in therapy for protected passive motion exercises and wound care. Protected passive motion exercises are done with the wrist in flexion and the repair is protected by adjacent joints being held in flexion while a joint is being extended. In the intermediate stage (3 to 4 weeks) the splint is extended to neutral and exercises are done hourly. These exercises include ten repetitions of passive flexion and active extension and ten repetitions of active tendon gliding exercises. To decrease the tension on the repair these exercises initially incorporate a tenodesis action at the wrist (wrist extension with finger flexion, and wrist flexion with finger extension). In the late stage (4 to 6 weeks), the splint is discontinued and gentle blocking exercises are done for isolated FDS and FDP glide and differential tendon gliding exercises.

With a long period of immobilization, there is typically an increase in edema and a decrease in tissue mobility with significant scar adhesion or tendon shortening limiting motion. This may require serial static splinting in a long wrist/finger splint or serial splinting or casting of PIP joint contractures, dynamic extension splinting may also be used to address contractures. If adhesions are limiting FDS glide, DIP extension splints can be worn to facilitate FDS glide during exercises. Intrinsic tightness can also be a
problem and is treated with additional exercises into a hook fist position. Stubborn adhesions can also be addressed with use of massage over the tendon while it is held in tension or on stretch, neuromuscular electrical stimulation to illicit a stronger muscle contraction, or ultrasound with stretch or active tendon pull.

Research has consistently shown that early mobilization of postoperative flexor tendons significantly improves the therapy outcome by decreasing restrictive adhesions, promoting synovial diffusion and intrinsic tendon healing, and modifying the gliding surface of the tendon (Gelberman & Manske, 1985; Gelberman & Woo, 1989; Kubota, H. et al., 1996; Stewart Pettengill & van Strien, 2002; & Strickland, 1989). Early passive mobilization is typically based on protocols developed by Kleinert, et al., (1967, 1975), and Duran and Houser (1975). They are based on the observation that 3 to 5 mm of glide was sufficient to prevent problematic adhesion formation. Most therapists currently use a modified version of one or the other or both. Both protocols use a dorsal blocking splint in wrist and MP flexion, which places the tendon on slack preventing tendon rupture. The Duran splint places the wrist in 20° flexion and MPs in a “relaxed position of flexion”, while the Kleinert splint uses 45° flexion at the wrist and initially 10° to 20° flexion at the MPs (modified later to 40°). Both splints used dynamic traction to maintain the fingers in flexion, but allow active extension into the limits of the splint. Slattery and McGrouther (1984) modified the traction by adding a palmar bar or pulley to the splint, which facilitated increased DIP flexion. The Kleinert protocol included ten repetitions of active extension into the limits of the splint ten times per hour. Exercise in the Duran protocol included protected passive range of motion of each joint six to eight repetitions twice a day. The Duran protocol also added a wrist cuff with rubberband flexion traction at 3
weeks to initiate active motion protecting the tendon. Currently most therapists are using a modified Duran protocol where the splint places the wrist in $20^\circ$ flexion and the MPs in $40^\circ$ to $50^\circ$ flexion, with IPs strapped into complete extension within the splint during non-exercise times. This tends to prevent the PIP flexion contractures that were common with the initial protocols using rubberband traction. The decreased flexion at the wrist also provided increased space in the carpal tunnel to prevent median nerve compression. In this modified program, patients passively flex joints individually and compositely and actively extend within the limits of the splint. Further modification done only in therapy sessions includes removal of the splint for protected synergistic exercises. These exercises use the synergistic movements of the wrist to decrease the stress on the tendons during active or active assisted range of motion. Tanka et al (2005), modified these exercises to include a hook fist pattern with wrist extension to further increase the proximal pull on the tendon. Cannon, et al. (2001) developed a protocol using a wrist hinge splint, blocking extension at $30^\circ$, so that synergistic exercises could be done multiple times a day on a home program basis. Although primarily designed for zone 2, these protocols are used for laceration repairs in all flexor tendon zones with variable adjustments. In other zones adhesions are less of a problem, however, the controlled stress still improves healing and scar remodeling resulting in improved outcomes. Evans (1990) has published a protocol specific to zone 1 tendon repairs. This protocol includes a dorsal gutter splint that is taped just proximal to the DIP joint holding it at $45^\circ$ flexion. The dorsal blocking splint is fabricated with wrist flexion at $30^\circ$ to $40^\circ$ and MP joints at $30^\circ$ flexion. The MP is positioned at $30^\circ$ to decrease the viscoelastic effect of the lumbrical on the profundus tendon. When MP flexion is greater, the lumbricals shorten
and the FDP can glide distally making it difficult to position the repair site proximal to its resting position.

In zone 4 the tendons lie in extremely close proximity to one another as they pass through the carpal tunnel. This makes them prone to adhesions between the tendons, making individual tendon gliding difficult (Stewart Pettengill, & van Strien, 2002). Therefore, differential tendon gliding exercises are extremely important for lacerations in this zone as well as in zone 2 where the profundus and superficialis lie so close together.

Rehabilitation of flexor tendon laceration in the thumb adds some different challenges. Due to the fact that there is only one tendon and a lesser number of vincula to that tendon, there is a greater tendency for the flexor pollicis longus (FPL) to retract proximally even down into the forearm. If repair is not immediate, the muscle, when held in this shortened position, will tend to shorten causing an increase in tendon tension following repair (Elliot & Southgate, 2005). There is also a decreased vascular supply to the FPL immediately palmar to the metacarpophalangeal joint, which may be responsible for a rupture rate that is twice as common in zone 2 as zone 1 repairs (Hergenroeder, Gelberman, & Akeson, 1982). Post operative splinting following FPL repair is variable as some authors recommend including the fingers, as finger flexion when making a fist includes IP flexion of the thumb (Elliot & Southgate, 2005) and some do not as significant amounts of IP flexion are not observed until finger flexion end range. Elliot and Southgate (2005) also incorporated a slight ulnar deviation in their splint (10°) design to reduce the turning angle of the FPL as it passes from the carpal tunnel into the thenar muscles. Cannon, et al. (2001) utilize an early active motion program that incorporates tenodesis / synergistic exercises similar to the one they use for the finger flexors.
With stronger suture techniques, further research indicating the benefits of early motion on healing, and the realization by therapists that their patients that "cheat" with active motion do better, increased motion has been added to tendon protocols. With passive mobilization the tendon is pushed proximally and can therefore bunch up as it passes through the sheath. With active mobilization there is pulling on the tendon proximally producing better glide (Silfverskiold, May, & Tornvall, 1992). There have been a variety of early active mobilization protocols developed varying from using dynamic flexion traction with rubberbands (Gratton, 1993), splinting which allows synergistic motion but extension blocking protection with a splint (Cannon et al., 2001; Strickland, 2005), to place and hold exercises relying on the patient's ability to monitor their strength of contraction and extension (Stewart Pettengill & van Strien, 2002), and modifications to include hook fist positioning (Tanaka et al., 2005). All of these protocols use a dorsal blocking splint, such as in the modified Duran protocol, for protection during non-exercise times. Most of the research indicates that choice of protocol and progression is based on therapist experience and judgment. Groth (2004) published a model of exercise progression based on a pyramid of progressive forces required for performance of specific exercises. This pyramid provides guidance for exercise progression based on the force requirements of eight specific rehabilitation exercises. The exercises progress from passive protected extension, to place and hold, to active composite fistling, to hook and straight fistling, to isolated joint motion, to discontinuing use of protective splinting, to resisted composite fist, to resisted hook and straight fist, and finally to resisted isolated joint motion. Progression up the pyramid is based on the active flexion lag present. It
serves to provide guidelines to assist in overcoming tendon gliding resistance for maximal excursion and avoiding excessive tendon loading.

Extensor Tendon Rehabilitation

Although there has been a great deal of research on flexor tendon repair and rehabilitation, there has been much less focus on the extensor tendons. This is somewhat surprising as extensor tendon injuries can be just as detrimental to functional hand use as injuries to the flexors (Newport & Tucker, 2005). As the extensors lie on the dorsum of the hand and fingers, where there is minimal soft tissue coverage, they are vulnerable to injury. Although weaker in strength than the flexors, the extensor tendons are responsible for maintaining the balance of the hand, and without their proper function can result in hand posturing that inhibits functional use (Rosenthal, 2002). As the extensor tendons are quite prone to adhesion formation in their healing process, injury often results not only in loss of extension, but in loss of flexion as well with the resulting limitation in tendon glide and excursion. Early motion in the rehabilitation program can facilitate increased tendon excursion and result in improved extension as well as flexion (Crosby & Wehbe, 1999; Evans, 1986, Khandwala, et. al, 2000; McDowell & Snider 1977; Strickland 1989; & Sylaidis, Youatt, & Logan 1997). Repaired extensor tendons are approximately 50% as strong as flexor tendons, because of reduced tendon dimension and the lack of collagen crosslinking (Rosenthal, 2002). As injuries to the extensor tendons typically involve the dorsum of the hand, there is frequently a great deal of edema over the dorsal surface. When this occurs, biomechanically we see the wrist flex, the MPs hyperextend and the IPs positioned in flexion. If not prevented, this position will
result in flexion contractures and loss of range of motion and function (Villeco, Mackin, & Hunter, 2002).

Like the flexor tendons, surgery and therapy are described in terms of the tendon zone where the injury has occurred (Evans, 2002). With flexor tendons, treatment is similar throughout all the zones. Extensor tendons have very different characteristics in each of the tendon zones, where injury results in biomechanical changes in hand posturing with significantly different needs at each level. Therefore tendon protocols are very different depending on the zone affected. The therapy goals in all zones, however, are the same: to protect the tendon repair (or position for intrinsic healing in a closed injury), prevent rupture or gap formation, promote tendon healing, facilitate tendon glide to full tendon excursion, and return to function.

Rehabilitation of extensor tendons that are closed is typically done without surgery in zones 1 and 2, and often also in zones 3 and 4. In a zone 1 and 2 injury, most research recommends 6 to 8 weeks of immobilization of the DIP joint with extension splinting following injury or surgery (Evans, 2002). Evans recommends that when motion is initiated it be gradual, which has also been found by this author to be critical in preventing extensor lag although not mentioned in many protocols. If the PIP joint begins to hyperextend producing a swan neck position, the PIP should be splinted in 30° to 45° flexion with the DIP extended. This will assist in a closer position of the torn tendon ends over the DIP by advancing the lateral bands.

An extensor tendon injury in zone 3 and 4 results in a boutonniere deformity (PIP flexion and DIP hyperextension), (Rosenthal, 2002). Injury in these zones typically involves disruption of the central slip. Without the support of the central slip, the lateral
bands migrate volarly flexing the PIP joint. The distal phalanx extends and the intrinsics and the extensors migrate proximally. With this positioning it is important to splint the PIP joint in complete extension to approximate tendon ends and facilitate healing (Froelich, Akelman, Herndon, 1988). A typical protocol for a zone 3 and 4 laceration is to immobilize for six weeks. The rationale behind this long immobilization is that the flexors are stronger than the extensors, so extensor tightness is easier to overcome than extensor lag. However, in this amount of time the extensor apparatus can become severely adhered and the PIP joint very stiff limiting flexion as well as extension, so most therapists begin gentle flexion exercises between 3 and 6 weeks. Initially active extension exercises are done with the MP in flexion, as MP flexion decreases the tension on the central tendon because of sagittal band distal migration, and flexion exercises are begun gradually and extensor lag monitored.

Newport, Blair, and Steyers (1990), did a study on the long term results of extensor tendon repair with follow-up treatment including immobilization. They discovered that poorer results were obtained in the fingers than in more proximal injuries among those having injuries in zones 3 and 4 with significant extensor lag and loss of flexion. This is due to the broad bone/tendon interface of the extensor system over the proximal phalanx, which adheres down easily with scar formation. Evans (2002), who has done a great deal of literature review, research, and clinical treatment on extensor tendons, has developed a protocol of immediate active short arc motion for tendon repairs in zones 3 and 4 for which she outlines in detail the anatomical, biochemical, and biomechanical rationale for its use. This protocol, called the Short Arc Motion (SAM), is a progression of active exercises within a limited arc. The wrist is positioned in 30° of
flexion during the exercises as this position reduces the flexor resistance and facilitates interossei function to extend the PIP joint, decreasing the stress on the extensor digitorum communis tendon during active extension. The MPs are at 0° and the PIP arc of motion is 0° to 30°. If the lateral bands have been repaired, DIP joint flexion is limited to 30°; if lateral bands were not injured DIP flexion is unrestrained. Beginning day one, these exercises are done 20 repetitions every hour into a template splint that blocks PIP flexion at 30° and another splint that maintains the PIP in extension while allowing the required DIP motion. The splint is then changed weekly to allow increased degrees of flexion. Evans (1994) research comparing this protocol to immobilization indicated improved results in digit flexion with less extension lag following use of short arc active motion.

There are also several avenues of treatment of extensor tendon lacerations in zones 5, 6, and 7. These injuries are typically from a laceration or a crush. Treatment protocols are varied, however, the rationale behind each is sound and the research results (although primarily isolated studies) are good in all, making it difficult to determine the course of treatment. The immobilization protocols are used only with simple lacerations in children or very non-compliant patients and are not used with crush injuries that involve multiple structures, due to the adhesions that would develop (Evans 2002). Splints fabricated for immobilization of the repaired tendon typically are in 30° to 45° wrist extension, MPs between 0° and 20° flexion and IPs at 0°. It has been controversial for years whether adjacent fingers should be included in the splint. Inclusion depends primarily on the location of the laceration in relationship to the juncturae tendinum. If proximal to the juncturae tendinum, then all fingers need to be included. If distal, then
only the involved digit is held in extension, while the adjacent fingers are allowed MP flexion to 30° (Beasley, 1981).

Immediate active motion with use of a dynamic extension splint was described by Evans and Thompson (1993) with a variety of modifications used in clinical practice. This splint assists extension dynamically. Flexion is done actively, but is limited typically to 30°. Evans does this with an additional volar based splint worn with the dynamic extension splint. Crosby, Wehbe, and Mawr (1999) limit the flexion in the splint by adding a washer to the dynamic traction bands. Howell, Merritt, and Robinson (2005) have designed a program that uses a yoke splint. This splint is made in two pieces: a volar wrist splint that holds the wrist in 20° to 25° extension, and a yoke that is wrapped under the injured finger and over the adjacent fingers, supporting the MP joints in slight hyperextension. This splint allows active motion, but does not put tension on the repair. Although this protocol is not currently used by most therapists, research results indicate excellent tendon function, with the advantage that the splint permits immediate active motion and participation in functional activities.

There are few studies that address the extensor pollicis longus tendon individually. Elliot and Southgate (2005) state in their study that tendon adherence by scar tissue to the underlying bone and overlying skin as well as thickening by scar tissue of the dorsal joint capsules, explains the loss of thumb movement following EPL repair. Typically loss of extension is an active loss and passive extension is possible. Even if there is a loss of active extension, it is rarely a problem functionally, however, loss of active flexion can cause functional disability. Protocols for EPL repairs typically involve
a dynamic thumb extension splint facilitating early motion (Cannon, et al., 2001; Clark, et al., 1998; & Evans, 2002).

Summary

Tendon rehabilitation continues to be challenging for surgeons and therapists. Many of the questions asked when surgeons first began repairing tendons, continue to be questions addressed in today’s research and clinical practice. The increased amount of research done over the past several years has provided information regarding surgical technique and therapy treatment that has improved hand surgeons’ and therapists’ abilities to facilitate improved tendon healing and function. However, although the rationale for therapy treatment is similar, a variety of protocols have been established to achieve those therapy goals. As the research is limited regarding each of these protocols with minimal research comparing the outcomes, it is difficult for therapists to decide which protocols and therapy techniques to utilize in patient care. It is even more difficult to determine the minor variations that need to be made in a protocol depending on individual patient needs and goals. This literature review has established rationale for use of many therapy techniques. It is the goal of this scholarly project that by combining this information with techniques learned in clinical practice, user friendly protocols in an algorithm format can be established. Therapists who are new to the field of occupational / hand therapy or who do not see hand patients on a regular basis will be guided through the clinical reasoning process and therefore provide their patients with not only adequate therapy, but good therapy achieving excellent results in hand and patient function.
CHAPTER III

METHODOLOGY

My work in the field of occupational therapy and especially in my clinical practice as a certified hand therapist, has helped me to realize that hand rehabilitation protocols are only a guide and a starting point from which to deviate. It is in keeping up with current research and experience in patient treatment, that one develops the clinical reasoning skills to provide the best possible treatment for hand patients and therefore achieve the best possible clinical outcomes. My experience as a teacher of hand rehabilitation and splinting to students studying for their occupational therapy degree, has made me realize that these students will rely on black and white protocols as they enter the field of practice and begin seeing hand patients. As a therapist who frequently consults with other clinical therapists regarding hand rehabilitation patients, I have also realized that those who see hand patients infrequently often do not feel comfortable with hand patient care, therefore they rely on standard protocols to guide their practice. This is especially true in rural settings where an occupational therapist may be a solo practitioner without a group of colleagues with which to share ideas. So the challenge was: How can I provide occupational therapists who are new graduates and those who see hand patients only occasionally with the clinical reasoning skills to not only provide adequate treatment, but to provide quality treatment facilitating excellent outcomes?

My idea for the solution to this problem was to develop a manual of hand therapy protocols that are organized in a concise and easy to follow algorithm format that includes all the clinical reasoning for the guidance on how one might deviate from the protocol if certain observations are made. Treatment would be organized on a week to
week time format based on the physiology of the tissue healing process, as well as on individual patient observations. Areas of treatment specifically addressed in the manual would include: wound care / scar control, splinting, exercises and activities, and activities of daily living / work activities.

Originally, it was planned to create this manual addressing all commonly seen distal upper extremity diagnoses, however, it was realized that this would be a huge project and beyond the scope of the time frame allowed for this project’s completion. So it was decided to narrow the area addressed to tendon rehabilitation, as this is one area where knowledge about and timing of treatment techniques during the healing process is crucial to achieving positive patient outcomes.

In the process of creating this manual, an extensive literature review was done. It became the realization of this author that time would not allow for the review of all research available over the past fifty years, so the focus was placed on reviewing articles that specifically addressed tendon surgery, healing, and therapy protocols, with an emphasis on recent publications. It was also discovered that there are many areas where more research would be beneficial to the hand surgery / therapy profession. As I had anticipated from a great deal of previous reading in generally keeping up with the hand rehabilitation literature, there were not black and white, never fail, treatment protocols for tendon injuries and many of the protocols and recommendations for patient treatment of one author did not agree with those by other authors reviewed. This was where clinical experience in treating hand patients was brought into the writing. Through clinical experience in using different therapy techniques, knowledge has been gained and was
incorporated with logical reasoning and consideration of the research reviewed in the manual’s development.

In addition to the visual algorithm format, drawings of many of the splints and exercises were also included to facilitate easy reference and use. In sharing these drawings and the protocols with experienced hand therapists, they were quite excited about both. They especially liked the detailed drawings and encouraged me to include more. Following this feedback, it was decided to also include an appendix of splint fabrication instructions and patterns as well as home program exercises.

Following completion of the initial flexor tendon protocol, the protocol was used as a teaching tool with students in an entry-level occupational therapy masters program. It was discovered that through the organization of the protocol, information could be covered more quickly allowing more time to be spent on the treatment techniques involved and providing more information in a hands-on format increasing student participation and understanding. The students stated that they loved the visual format with the picture drawings. They reported that it was easy to follow and facilitated their understanding.

The following pages contain the protocol manual for treatment of tendon lacerations/repairs. Subsections include: Flexor and Extensor Anatomy organized by tendon zones, Flexor Tendon Repair algorithm protocol, Flexor Pollicis Longus Repair algorithm protocol, Extensor Tendon Rehabilitation protocols organized per closed injury and post surgical cases specific to tendon zones, and Extensor Pollicis Longus Repair protocol. The appendix of the manual is organized into two sections. One includes the fabrication instructions and patterns for each of the splints mentioned in the protocols.
The other includes home program handouts that could be provided to patients in their therapy treatment sessions. It is the hope that this manual and its organization will provide therapists with an easy to use tool that includes clinical reasoning to adapt from the typical protocol, as well as, easy to access instructions for splint fabrication and home program handouts for patients. The ultimate goal of this manual is to assist therapists in providing not only adequate, but exceptional therapy to patients with tendon injuries resulting in excellent clinical outcomes. The other goal for this manual is that it can be used as a teaching tool to instruct students in a well organized, concise, and understandable format that will facilitate their learning to become therapists that can help their patients achieve excellent clinical results.
CHAPTER IV

PRODUCT

Review of the literature combined with clinical practice in treating hand therapy patients and teaching students who are studying to enter occupational therapy practice in which hand therapy may be a part, lead to the development of this manual, "Tendon Rehabilitation: A Manual of Algorithm Protocols for Therapists". This manual presents tendon rehabilitation protocols in an algorithm format, following a biomechanical frame of reference. These protocols bring the therapist or student through specific tendon rehabilitation, providing not only basic protocol to follow in treating tendon patients, but also including clinical reasoning to guide the therapist in recognizing patient progress and difficulty, and problem solving to progress the therapy toward the established goals. It is the goal that with guidance from this manual, even newly graduated therapists and therapists who do not see hand patients on a regular basis will be able to provide not only adequate, but excellent therapy services and outcomes.

This manual begins with flexor and extensor tendon anatomy and the description of the tendon zones. This is presented in a concise outline format with a detailed drawing that includes not only the surface outline that is available in most of the research, but also the other anatomical structures present in each of the zones including: skin and joint creases, bones, tendons, sheaths, fascia and pulleys, vascular and nerve tissue. The zones are easily referenced so that therapists can be made aware at a glance of not only the
tendons within a zone area, but also the other anatomical structures that may have been
injured or need to be considered in a rehabilitation situation.

Therapy protocols within this manual are for post-operative flexor tendon
rehabilitation of the fingers and thumb, as well as extensor tendon rehabilitation for
closed as well as post-surgical injuries, and are described in reference to tendon zones.
Protocols are presented in an easy-to-follow block format guiding treatment on a week­
to-week basis. Treatment techniques include splinting, exercises, activities of daily living,
and modalities. Specific directions and drawings are included to increase understanding
and treatment guidance.

In addition to the algorithm protocols, the appendix contains fabrication
instructions and patterns for each of the splints, as well as handouts for home program
exercises. These home program handouts include detailed drawings and concise
instructions for clarity and ease in following for good compliance.

It is the goal that this tendon rehabilitation manual in an algorithm format will
provide entry level or inexperienced therapists with a guide that includes clinical
reasoning, so that patients can be provided with not only adequate but excellent therapy
services and outcomes. It is also the goal that this manual will serve as a guide for
therapists who see hand therapy patients on a regular basis, with treatment guidance to be
combined with skills gained through experience to provide excellent patient care. It is
also the hope that the splint fabrication instructions will make fabrication of the splints
within the protocols easy and accurate. The home program handouts, with clear concise
instructions and drawings, could be used to improve home program compliance. It is felt
that this manual could also be used when teaching occupational therapy students to provide good understanding of tendon rehabilitation and clinical problem solving.
TENDON INJURY REHABILITATION

A Manual of Algorithm Protocols for Therapists

Joni Armstrong
TENDON INJURY REHABILITATION
A Manual of Algorithm Protocols for Therapists

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Flexor Tendon Anatomy and Zones

Zone 1: Distal to the superficialis.
- Profundus tendon & insertion
- DIP joint
- Digital nerves & arteries
- A5 & C3 pulleys

Zone 2: “No Mans Land”
From the A-1 pulley to the insertion of the superficialis tendon.
- Superficialis tendon and insertion (Splits to allow FDP to pass through )
- Profundus tendon
- PIP & MP joints
- Digital nerves and arteries
- A1, A2, A3, & A4, C1 & C2 pulleys
- Lumbrical & palmar interossei insertions
- Vinculum to the FDS & FDP

Zone 3: Distal end of the carpal tunnel to the A1 pulley.
- Superficialis & profundus tendons
- Lumbricals, palmar interossei
- Thenar and hypothenar muscles
- Arches of the radial and ulnar arteries
- Median & ulnar nerves branching into digital nerves
- Palmar aponeurosis & metacarpal ligament

Zone 4: Carpal Tunnel area of the wrist
- Superficialis, Profundus, & FPL Tendons
- FCR, FCU, & Palmaris Longus insertions
- Median nerve passing through the carpal tunnel
- Ulnar nerve passing through guyon’s canal
- Flexor retinaculum
- Radial & ulnar arteries

Zone 5: Musculotendinous junction to the carpal tunnel (forearm)
- FCR, FCU, Palmaris Longus, Supinator, and Superficialis, Profundus, & FPL Tendons.
- Pronator quadratus
- Median & ulnar nerves
- Radial & ulnar arteries

Zone T1: IP joint & thumb tip.
- Flexor pollicis longus
- IP joint Digital nerves & arteries

Zone T2: A1 pulley to the IP joint.
- Flexor pollicis longus tendon
- Digital nerves & arteries
- A1, A2, & C1 pulleys

Zone T3: Thenar Eminence
- Flexor pollicis longus
- Thenar muscles
- Radial artery to the thumb
- Thenar branch of the median nerve

Synovial Sheaths
Extensor Tendon Anatomy and Zones

Zone 1: DIP Joint
- Terminal Extensor Insertion
- Nerve branches from the median nerve (2, 3, & ½ of 4), and ulnar nerve (5 & ½ of 4)

Zone 2: Middle Phalanx
- Conjoined Lateral Bands
- Triangular Ligament
- Oblique Retinacular Ligament

Zone 3: PIP Joint “Zone of Convergence”
- Central Slip
- Lateral Slip
- Transverse Retinacular Ligament

Zone 4: Proximal Phalanx
- Central Slip
- Branches from the radial nerve

Zone 5: MP Joint
- Central slip
- Sagittal Bands
- Lumbricals
- Interossei

Zone 6: Dorsum of the Hand
- Extensor Communis tendons
- Extensor Indices Proprius
- Extensor Digiti Minimi
- Junctura Tendinum
- Dorsal Interossei
- Dorsal venous arch

Zone 7: Dorsal Wrist
- Extensor Tendons
- Extensor Retinaculum: Tendons run through 6 separate synovium-lined compartments.
  1) EPB 2) ECR 3) EPL 4) EDC, EIP, 5) EDQ 6) ECU
- Wrist extensor insertions
- Radial nerve
- Cephalic & Basilic Veins

Zone 8: Proximal to the Extensor Retinaculum
- Musculotendonous junctions

Zone T1: IP Joint
- Extensor pollicis longus insertion

Zone T2: Proximal Phalanx
- Extensor pollicis longus tendon

Zone T3: MP Joint
- Extensor pollicis longus and brevis tendons
- Adductor pollicis expansion

Zone T4: 1st Metacarpal
- Extensor pollicis longus tendon
- Abductor pollicis longus
- Extensor pollicis brevis
- 1st dorsal interossei
- Radial artery
- Princeps pollicis artery

Zone T5: Dorsal Radial Wrist
- Extensor retinaculum: EPB – compartment 1
- EPL – compartment 3

(Odd numbers overlie the joints and even numbers overlie the intermediate tendon segments.)
ALGORITHM PROTOCOLS
Flexor Tendon Repairs
Post-Operative Therapy

1 to 3 weeks

Dorsal Blocking Splint – 24 hours
- Wrist 20° to 30° Flexion
- MPs 40° to 60° Flexion
- IPs Full Extension
- Fingers strapped into extension when not exercising

Edema control
- Elevation
- Gentle massage
- Tubigrip or coban

Exercises:
Passive Range of Motion Exercises: Every 1 to 2 hours within the splint
- Individual Joints
- Full Composite
Active extension into the splint
Scar Control
- Stitch removal at 10 to 14 days
- debridng
- Massage with moisturizer
- Elastomer patch (gel → Otoform)

ADL: No use of injured hand.

If finger is quite edematous and flexion is limited, add a dynamic flexion assist – Velcro to fingernail with rubberband attached to a pin in the wrist strap. Active extension can be done against the band.

3 to 4 weeks

Dorsal Blocking Splint can be removed, but hand use is not allowed. Splint is adapted to wrist at neutral and should be applied when the hand could be bumped and at night.

Exercises:
- Continue with passive flexion and active extension
- Begin or continue with tenodesis exercises
- Begin active assisted (place & hold) in composite patterns.

Edema control
- If edema is present do massage prior to exercises.
- Continue as above if still present

Scar Control
- Continue with massage and elastomer use

When a 4 strand or more repair has been done, there have been no tendon or nerve repairs at the wrist, edema is not extreme, and patient compliance is good, early active motion of synergistic exercises can be done through use of a wrist hinge splint that blocks extension at 30°, beginning at 5 days. The hinge splint is applied hourly for the exercises:
- fingers are passively flexed and the wrist is brought up to 30° extension
- this flexion is held actively
- as the wrist is brought into flexion the fingers extend

The dorsal blocking splint is worn between these exercise sessions, and passive motion protocol is also followed.

If increased composite flexion is desired (profundus repair) the band is passed through a second pin at the palmar strap increasing DIP flexion.

If DIP has limited flexion, a DIP dorsal gutter splint is added at 35° to 45° flexion during non-exercise times.

If patient is extremely compliant, synergistic exercises can be done without the splint. This can also include the hook fist position.

In combined flexor & extensor repairs, the wrist is splinted in neutral, with MPs in flexion and IPs extended. Tendon excursion is only partial and is protected.

Pulley repairs need to be protected for 4 to 6 months by applying pressure during active flexion manually or through use of a pulley ring.
4 to 8 weeks

Discontinue Splinting

Exercises
- Continue with passive and active assisted range of motion exercises.
- Begin active range of motion exercises
  - Tendon Gliding
  - Blocking (6 weeks)
  - Begin light active use (picking up sponges)
  - Superficialis/Profundus tendon isolation exercises

Scar Control
- Continue with elastomer use
- If adherence is noted between the tendon and skin (pulls with active tendon use), increase massage to that area during active tendon use.

ADL: Injured hand used as an assist for non-resistive activities

If there is limitation in composite extension, serial static splinting into maximum extension is initiated, and composite extension stretch added.

If FDS glide is limited, use DIP extension splints during exercises.

If passive motion is greater than active indicating limited tendon excursion and probable adhesion use:
- Heat modalities – prior to exercises
- Ultra sound – Best results are seen when the tendon is placed on active tension
- Electric stimulation
- Active ROM exercises
- Resistive exercises
- Splinting of specific joints if passive ROM continues to be limited
8 to 12 weeks

Resistive exercises to increase strength and endurance
  - Emphasize exercises combining wrist and finger motions.
  - Dexterity exercises
Begin full use in ADL and work simulation
Continue with splinting and modalities if tendon excursion is not complete.

> 12 weeks

If full range motion is not achieved by 12 weeks, an aggressive approach can be taken:
  - Ultrasound while the tendon is placed on stretch and when active resisted flexion is being done.
  - Massage across the tendon while the tendon is being actively flexed.
  - Full active use with resistive exercises specific to the tendon.
**Flexor Pollicis Longus Repair**

Post-Operative Therapy

1 to 3 weeks

<table>
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<tr>
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<tr>
<td><strong>Wrist</strong> 20° flexion and 10° ulnar deviation</td>
</tr>
<tr>
<td>- CMC in partial palmar abduction</td>
</tr>
<tr>
<td>- MP 15° to 30° flexion</td>
</tr>
<tr>
<td>- IP 0° flexion</td>
</tr>
<tr>
<td>(If zone 2, then splint IP in 30° flexion.)</td>
</tr>
<tr>
<td><strong>Edema Control:</strong></td>
</tr>
<tr>
<td>- Elevation</td>
</tr>
<tr>
<td>- Gentle massage</td>
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<td><strong>Exercises:</strong></td>
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<td><strong>Passive Range of Motion Exercises within the splint</strong></td>
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<tr>
<td>- Individual Joints</td>
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<tr>
<td>- Full Composite</td>
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<tr>
<td>- IP extension with MP flexion block</td>
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<td>- Active extension into the splint</td>
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</table>

If thumb is quite edematous and flexion is limited, add a dynamic flexion assist – Velcro to fingernail with rubberband attached to a pin on the strap at the base of the 5th digit. Active extension can be done against the band.

When a 4 strand or more repair has been done, edema is not extreme, and patient compliance is good, early active motion with tenodesis exercises can be done through use of a hinge splint that blocks wrist extension at 30°, beginning at 3 days. The hinge splint is applied every 2 hours for 15 repetitions of exercise:

- thumb is passively flexed and the wrist is brought into 30° extension
- the flexion is held actively for 5 seconds
- the wrist is relaxed into flexion and the thumb extended

Also include scar and edema control and passive range of motion exercises.
Continue 1 to 3 Weeks

Scar Control:
- Stitch removal at 10 to 14 days
- Debriding
- Massage with moisturizer
- Elastomer patch (gel → Otoform)

ADL: Splint applied at all times. No use of involved hand for daily activities.

3 to 4 Weeks

Splinting: Continue with dorsal blocking splint.

Exercise: Following massage and passive range of motion, begin composite active flexion and extension within the splint 20x every 1 to 2 hours.

Continue with edema and scar control.

If there is a significant difference between active and passive range of motion use:
- Heal modalities prior to exercise
- ultrasound
- electric stimulation
- massage

4 to 6 weeks

Splinting: Continue with dorsal blocking splint at night and between exercises. If there is tightness and limitation in composite extension decrease wrist angle to neutral.

Exercises: Add active assisted and active range of motion exercises with splint removed: IP and MP Flexion and extension in isolated patterns and various positions of the CMC joint as well as composite flexion. Continue with active extension, blocking the MP into flexion during IP extension.
5 to 6 Weeks

Splinting: Discontinue dorsal blocking splint.
Exercises: Continue with passive and active range of motion exercises. Add sponge exercises and picking up of light objects with pinch patterns.
Continue with scar and edema control.
ADL: Use of the injured hand in light activities.

7 to 8 Weeks

Begin strengthening exercises, progressing gradually.
ADL: Use of injured hand in activities. Avoid heavy lifting and activities that involve sustained pinch.

10 to 12 Weeks

Unrestricted hand use and return to pre-injury activities.

If full range of motion is not achieved by 10 to 12 weeks, an aggressive approach can be taken:
- Ultrasound while the tendon is placed on stretch and when active resisted flexion is being done.
- Massage across the tendon while the tendon is being actively flexed.
- Full active use with resistive exercises specific to the FPL.

If passive extension is limited, serial static splinting into maximum extension is initiated, and composite extension stretch added.

If limitation is strictly intrinsic, the extension splint can be hand-based.
Extensor Tendon Rehabilitation

Zone 1 & 2: Mallet Finger: DIP drops into flexion

Laceration, rupture, or evulsion of the terminal extensor tendon, results in lack of DIP extension.

0-6 weeks

Volar gutter splint:
- In slight DIP hyperextension (Move the DIP into hyperextension until blanching occurs, then back off hyperextension until color is normal – this is the position to splint.) The splint is applied with tape and worn 24 hours/day, with removal 1x/day for hygiene while hyperextension is maintained.
- Passive & Active ROM to the MP and PIP joints.

Exercises:
- Passive & Active ROM to the MP and PIP joints.

If skin over the DIP becomes irritated or macerated, place a small piece of moleskin or gauze between the DIP and the tape, still securing the tape to the finger on either side. Gel elastomer can also be used if there is wound or scar on the dorsal joint.

If edema is significant, the splint will need to be checked and adjusted for ideal fit as edema decreases.

If PIP hyperextension is present (swan neck deformity) then splint the PIP in slight flexion (about 30°) while maintaining the DIP in slight hyperextension.

7 weeks

Splinting: Continue use of the volar gutter splint when not exercising and at night.
Exercises: Begin limited active DIP flexion to 20° to 25° and active extension to 0°, 10x every two hours.

If the patient has a difficult time judging the degrees of active flexion, a template splint can be fabricated and used during exercise sessions.

If at any time an extensor lag develops, increase splint wear balancing with active motion and exercises.

8 weeks

Splinting: Continue use of the volar gutter splint when not exercising and at night.
Exercises: Increase degrees of flexion to 35° to 45° with active extension to 0°, 10x, every two hours.

If at any time an extensor lag develops, resplint and delay exercise for 2 weeks.

9 to 12 weeks

Splinting: Continue use of the volar gutter splint only at night.
Exercises: Continue with moderate DIP flexion, gradually adding increased resistance for strengthening, as well as prehension and dexterity exercises. Stop splinting, begin using complete DIP flexion, with unrestricted use at 12 weeks.

If at any time an extensor lag develops increase splint wear balancing with active motion and exercises.
Zone 3 & 4: Boutonniere Deformity: PIP flexion and DIP hyperextension

With laceration of the central slip, the lateral bands migrate volarly flexing the PIP joint. The distal phalanx extends and the intrinsics and the extensors migrate proximally.

Non-operative – closed injury
0 to 4 or 6 Weeks

**PIP extension splint in absolute 0°:**
- Cylindrical thermoplastic allowing MP and DIP flexion.
- or Cylindrical plaster casting (changed weekly)
  As edema decreases the splint will have to be replaced periodically to accommodate.

**Exercises:**
- DIP flexion active and passive within the splint
  ADL:
  Use of injured hand in all activities with splint applied.
- Active ROM to all other joints

5 to 6 weeks

Exercises: PIP flexion 25° to 30° and extension to 0°, 10 to 20 x, every 2 hours.
(If the patient has difficulty judging degrees of motion, a template splint is used.)

Splinting: Continue PIP extension splinting at night and between exercise sessions.

If edema is extreme, the finger is wrapped in coban and a volar gutter splint applied in 0° PIP extension with tape, until edema decreases and a cylindrical splint can be applied.

If the oblique retinacular ligaments are tight limiting DIP flexion, add a dynamic flexion component to the cylindrical splint or cast.

If MP hyperextension is seen with increased PIP flexion, splint the MP in flexion along with PIP extension.

If extension lag is seen at any time, resplint and delay exercises for 1 to 2 weeks.

If ROM is limited consider use of ultrasound.
6 to 7 Weeks

**Exercises:**
- PIP flexion to 45° and active extension to 0°, 10 to 20x, every 2 hours.
  (If patient has difficulty judging degrees of motion, a template splint is used.)

**Splinting:**
Continue PIP extension splinting at night and between exercise sessions.

---

8 to 10 Weeks

**Exercises:**
- If extension has been maintained, begin full flexion exercises. If there has been some extension lag and resplinting, allow 60° flexion for 1 week, then progress to full flexion.
- Gentle passive flexion if PIP joint is tight.
- Include active extension exercises.

**Splinting:**
- Continue PIP extension splinting at night. If some extension lag has been experienced, periodic extension splinting during the day may be required.
- If PIP flexion is significantly limited, coban wrap, elastic sling, or dynamic flexion splinting should be added periodically throughout the day.

---

If at any time extensor lag develops, increase splint wear balancing with active motion and exercises.

If both extension and flexion are limited consider use of a dynamic PIP extension splint with a dynamic PIP flexion component, alternating during the day.
10 to 12 Weeks

<table>
<thead>
<tr>
<th>Exercises:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Continue with active and passive range of motion exercises for flexion</td>
</tr>
<tr>
<td>and extension.</td>
</tr>
<tr>
<td>- Add resistive exercises for strengthening for flexion and extension.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Splinting:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Discontinue extension splinting if extension is maintained.</td>
</tr>
<tr>
<td>- If flexion is not complete, continue with flexion splinting, or buddy</td>
</tr>
<tr>
<td>tape/strap to the adjacent finger.</td>
</tr>
</tbody>
</table>
Extensor Tendon Rehabilitation
Surgical Repair

Zone 3 & 4: Boutonniere Deformity: PIP flexion and DIP hyperextension

With laceration of the central slip, the lateral bands migrate volarly flexing the PIP joint. The distal phalanx extends and the intrinsics and the extensors migrate proximally.

Post-Surgical
If a patient is reliable to do exercises hourly and would like the advantage of only finger splinting during the day, use the Short Arc Motion protocol. If the patient is not reliable or unable to do the more specific hourly exercises, then use the dynamic splinting protocol.

Early Active Motion
Short Arc Motion (SAM) - Evans
0 to 2 Weeks

Splinting of PIP and DIP into 0° extension:
- Volar gutter splint taped to the digit (typically over coban wrap to also control edema), worn between all exercise sessions.

Exercise: Home Program
With the wrist held in 30° flexion and the MPs at 0°, complete active flexion into a template splint that allows 30° PIP flexion and 20° to 25° DIP flexion, and extend to 0°, 20x hourly.

Clinic Program:
- With wrist DIP.
- IP held in extension, flex the

If lateral bands did not require repair, complete DIP flexion and extension are done in a template splint 20x hourly.

If lateral bands have been repaired, only 30° flexion is allowed in the template splint.

Scar Control:
- Remove stitches at 10 to 14 days.
- Massage
- Elastomer patch (gel)

Edema Control:
- Coban wrap
- Gentle massage
- Elevation

ADL:
No limitations in hand use with extension splint applied.
2 Weeks:
Continue with use of the extension splint at night and between exercise sessions, as well as scar control. If no extensor lag is present, change the template to allow 40° PIP flexion. Complete flexion into the splint and extend to 0°, 20x hourly.

3 Weeks:
Continue with use of the extension splint at night and between exercise sessions, as well as scar control. If no extensor lag is present, change the template to allow 50° PIP flexion. Complete flexion into the splint and extend to 0°, 20x hourly.

4 Weeks:
Continue with use of the extension splint at night and between exercise sessions, as well as scar control. If no extensor lag is present, change the template to allow 70° to 80° PIP flexion. Complete flexion into the splint and extend to 0°, 20x hourly.
5 Weeks:

Splinting: Continue with extension splinting.

Exercises:
- Composite flexion exercises
- Light strengthening exercises

6 Weeks

If range of motion is complete, discharge with a strengthening home program.
ADL: No limitations.

If both extension and flexion are limited consider use of a dynamic PIP extension splint with a dynamic PIP flexion component, alternating during the day.

If there is a persistent extensor lag, continue with extension splinting.

If flexion is limited continue with flexion splinting (dynamic flexion splint, elastic cuff, buddy strapping), ultrasound, and exercises.
Early Passive Motion
Dynamic Splinting
1 to 3 Weeks

**Splinting:**
- Volar gutter splint taped to the digit (typically over coban wrap to also control edema), worn at night and at times when the dynamic splint is not applied.
- Hand-based dynamic extension splint with 30° flexion block.

**Clinic Program:**
With wrist, MP, and PIP held in extension, flex the DIP.

**ADL:** Light hand use within the limits of the splint.

**Home Program:**
Exercises within the splint. 20x every hour Actively flex the fingers to the 30° limit, then allow the splint to passively extend to 0°.

**Scar Control:**
- Remove stitches at 10 to 14 days.
- Massage
- Elastomer patch (gel)

**Edema Control:**
- Coban wrap
- Elevation
- Gentle massage
- Elevation

**ADL:**
Within limits of splint application.

3 to 4 Weeks

Continue with splinting and exercises.

If there is a passive extensor lag, position the MP joint in flexion within the dynamic splint.

Consider use of a static progressive assist instead of the dynamic periodically throughout the day.
4 Weeks

**Night Splinting:** Continue.

**Day Splinting:** Remove flexion blocks (washers) allowing full finger flexion.

**Exercises:** Continue as previously.
Add to hourly exercises:
- PIP extension with MP blocked into flexion.
- Tendon gliding exercises with wrist in extension.

---

If there is some degree of extensor lag:
- Use night extension splint periodically throughout the day.
- Increase flexion gradually by moving washer stops to allow only 10° to 20° increases per week.
- Scar mobilization
- Ultrasound
- Electric Stimulation

---

If there is limitation in flexion and scars are quite adherent:
- Massage with the finger in composite flexion.
- Utilize moist heat and ultrasound prior to exercises and massage.
- Use electric stimulation.

---

5 to 6 Weeks

**Splinting:** If no extensor lag, discontinue extension splinting gradually (1 to 2 hours /day monitoring for extensor lag).
**Exercises:** Finger extension exercises with light strengthening.

---

If there is limitation in digit flexion, begin dynamic flexion splinting (Can be easily added by attaching a safety pin to the palmar strap at the distal palmar crease), elastic flexion strap, buddy strapping, or taping.

**Flexion wrap in moist heat prior to exercise.**
**Exercises:**
- Passive and active blocking exercises

---

If both extension and flexion are limited consider use of a dynamic PIP extension splint with a dynamic PIP flexion component, alternating during the day.
### 7 to 10 Weeks

<table>
<thead>
<tr>
<th>Exercises: Progressive strengthening of both extensors and flexors.</th>
</tr>
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<tbody>
<tr>
<td>ADL: Use of the injured hand in most activities that do not require lifting of heavy weights.</td>
</tr>
</tbody>
</table>
Zones 5 & 6
Post-Surgical
1 to 3 Weeks

Night Splinting:
Volar splint with wrist in 30° to 40° extension.
Fingers in 0° extension if laceration is proximal to the juncturae tendinum

If distal to the juncturae tendinum then the adjacent MPs can be in 30° flexion and IPs free.

Day Splinting:
Dynamic finger extension splint, with wrist positioned in 40° extension, and finger stops that allow flexion to 30°.

Home Program Exercises: 20x every hour. Actively flex the fingers to the 30° limit, then allow the splint to passively extend.

Clinic Program:
• Synergistic Exercises: Passive motion into maximum wrist extension with MP joint flexion to 40°, then wrist flexion to 20° with finger joints held in extension.
• Protected Passive Range of Motion

If only the extensor indices or the extensor digit minimi are lacerated, then only the involved finger needs to be included in the splint.

If good flexion is not seen in the MP joints, use a wider sling (made from Velcro or moleskin) or insert a volar gutter splint to eliminate PIP flexion and concentrate the force on the MPs.

In combined flexor & extensor repairs, the wrist is splinted in neutral, with MPS in flexion and IPs extended. Tendon excursion is only partial and is protected.

MP Flexion with wrist & PIP extended
Individual joint flexion with wrist and MPs extended
Continue: 1 to 3 Weeks

Scar control:
- Stitch removal at 10 to 14 days.
- Debriding
- Massage with moisturizer
- Elastomer patch (gel → Otoform)

Edema control:
- Massage
- Elevation
- Compression glove
- Coban wrap

ADL: No use of the injured hand.

↓

3 to 4 weeks

Night Splinting: Continue.

Day Splinting: Remove flexion blocks (washers) allowing full finger flexion.

Exercises: Continue as previously.
Add to hourly exercises:
- Synergistic exercises to full composite flexion.
- Tendon gliding exercises with wrist in extension:

ADL: Use in light activity with dynamic splint applied.

If there is some degree of extensor lag:
- Use night extension splint periodically throughout the day.
- Increase flexion gradually by moving washer stops to allow only 10° to 20° increases per week.
- Scar mobilization
- Ultrasound
- Electric Stimulation

If there is limitation in flexion and scars are quite adherent:
- Stabilize the skin proximal to where the scar is adhered and flex the MPs.
- Utilize moist heat and ultrasound prior to exercises.
- Use electric stimulation
- Massage
5 to 6 weeks

If no extensor lag, discontinue night splinting.
Gradually decrease day splinting an hour or two / day, monitoring for any extensor lag, then discontinue.

Add isolated finger extension exercises.

ADL:
Use of injured hand in light activities without the splint.

7 to 10 Weeks

Exercises:
- Add full composite wrist and finger flexion.
- Progressive strengthening of both extensors and flexors.

ADL: Use of injured hand in most activities that do not require lifting of heavy weights.

If there is limitation in digit flexion, begin dynamic flexion splinting (Can be easily added by attaching a safety pin to the palmar strap at the distal palmar crease), elastic flexion strap, buddy strapping, or taping.

Flexion wrap in moist heat prior to exercise.
Exercises:
- Passive and active blocking exercises
Zone 5, 6, & 7
Post Surgical Immediate Controlled Active Motion (ICAM) Splint Program
(Consider for single tendon lacerations)
1 to 3 Weeks

Two part ICAM splint: Worn continuously.
- Wrist cock-up in 20° to 25° of extension.
- Finger yoke positioning the injured MP joint in 15° to 20° more extension relative to the uninjured MP joints.

Exercises: Full active flexion and extension.

Edema:
- Elevation
- Massage
- Compression glove
- Coban wrap

Scar Control:
- Stitch removal at 10 to 14 days.
- Debridging
- Massage with moisturizer
- Elastomer patch (gel → Otoform)

ADL: Use in light ADL activities with splints applied.

↓

3 to 5 Weeks

Discontinue use of the wrist cock-up for light activities, but continue to use it with medium to heavy tasks. The yoke is worn at all times.

Exercises:
- Continue with full active finger flexion and extension.
- Add wrist range of motion.

ADL: Unlimited use with both splints applied. Light use with only yoke splint applied.

↓

5 to 7 Weeks

Use only yoke splint.
Full active use in exercises and ADL.

↓

8 weeks

Discontinue splinting and discharge.
Zone 7
Post Surgical
1 to 3 Weeks

Night Splinting:
Volar splint with wrist in 30° to 40° extension, MPs in 0° extension, and IPs free to move.

Day Splinting:
Dynamic finger extension splint, with wrist positioned in 40°, and finger stops that allow flexion to 30°.

Home Program Exercises: 20x every hour. Actively flex the fingers to the 30° limit, then allow the splint to passively extend.

Clinic Program:
• Synergistic Exercises: Passive motion into maximum wrist extension with MP joint flexion to 40°, then wrist flexion to 20° with finger joints held in extension.
• Protected Passive Range of Motion:

MP Flexion with wrist & PIP extended
Individual joint flexion with wrist and MPs extended

If a PIP extension lag develops due to constant flexion at night, then include IP joints in the splint.

If only wrist extensors are repaired and no finger extensors are involved, then splint the wrist in 30° to 40° extension and leave the fingers free (Wrist cock-up).

Begin active extension in a gravity eliminated position at 3 weeks.

Begin active range of motion exercises and light hand use at 4 weeks, gradually adding increased wrist and finger flexion and ulnar and radial deviation.

Begin passive wrist and composite range of motion exercises at 5 to 6 weeks.

Add strengthening at 8 weeks and gradually progress.
Continue: 1 to 3 Weeks

Scar control:
- Stitch removal at 10 to 14 days.
- Debridimg
- Massage with moisturizer
- Elastomer patch (gel → Otoform)

Edema control:
- Massage
- Elevation
- Compression glove
- Coban wrap

ADL: No use of the injured hand.

4 to 5 Weeks

Night Splint: Continue

Day Splinting: Remove flexion blocks allowing full finger flexion.

Add to hourly exercises: Active:
- Tendon Gliding Exercises
- Isolated finger extension exercises:
  (Can tape PIPs and DIPS into flexion to maximize EDC excursion)

- Position the wrist in varying degrees of flexion and extension (from neutral to full flexion and full extension), then bring fingers into full composite flexion and extension.
- Radial and ulnar deviation of the wrist in flexion and extension with the forearm in supination and pronation.

ADL: Use of injured hand in light activity with dynamic extension splint or wrist cock-up splint applied.
6 Weeks:
Continue with dynamic extension splint between exercise sessions and static wrist and MP extension splint at night.

Exercises:
Add passive flexion of wrist and fingers in composite patterns.
Add passive isolated finger flexion.

If tendon excursion is limited or there is not good gliding between tendons, use:
- Ultrasound – Add a composite stretch into flexion during ultrasound.
- Electric stimulation – Tape IPs into flexion to isolate MP joints and maximize excursion.
- Massage over the dorsal wrist scar with tendon tension.

7 to 8 Weeks
Discontinue splint use.
Add progressive strengthening exercises.
Extensor Pollicis Longus Repair

Zone T1 & T2
1 to 8 Weeks --- Closed Injury / 1 to 6 Weeks --- Surgical Repair

Splint: Volar gutter splint with the IP in slight hyperextension (Move the IP into hyperextension until blanching occurs, then back off hyperextension until color is normal – this is the position to splint.)

Exercise: Home Program
- Passive and active MP flexion and extension.
- Radial and palmar abduction
- CMC rotation.

Passive MP flexion  Radial Abduction  Adduction  Palmar Abduction  Thumb Rotation

ADL:
No limitations in hand use with extension splint applied.

Scar Control:
- Remove stitches at 10 to 14 days.
- Massage
- Elastomer patch (gel)

Edema Control:
- Coban wrap
- Gentle massage
- Elevation

9 to 10 Weeks --- Closed Injury / 6 to 8 Weeks --- Surgical Repair

Exercises: IP flexion 20° and active maximum extension, 10 to 20 x, every 2 hours. Progress 20° each week.
(If the patient has difficulty judging degrees of motion, a template splint is used.)
Begin light pinching and gripping within the limited range of motion.

Splinting: Continue extension splinting at night and between exercise sessions.

ADL: No activity restrictions with splint applied.

If an extensor lag develops at any time, decrease the degrees of motion and continue extension splinting.
10 to 12 Weeks --- Closed Injury / 8 to 10 Weeks --- Surgical Repair

Splinting: If no extensor lag, discontinue splint use.
Exercises: Gradual strengthening with emphasis on pinch patterns.
ADL: Full use in activities, avoiding forceful sustained pinch.

Zones T3, T4, & T5
Post-Surgical
1 to 3 Weeks

Splinting:
- Night: Static splint in a position of 20° wrist extension, CMC between radial and palmar abduction, MP at 0°, and IP slightly hyperextended.
- Day: Dorsal dynamic splint in 30° to 40° wrist extension, CMC between radial and palmar abduction, MP at 0°, and dynamic sling supporting the IP joint in neutral allowing full flexion to 60°.

Home Program Exercises:
With dynamic splint applied, flex thumb to 60° 20x each hour.

Clinic Program:
With splint removed and wrist maintained in extension:
- With IP in extension, bend the MP into full flexion.
- With MP in extension, bend the IP into full flexion.
- With wrist in 20° extension, bring the thumb into complete extension and gently hold.

Scar Control:
- Remove stitches at 10 to 14 days.
- Massage
- Elastomer patch (gel)
- Digit caps

Edema Control:
- Coban wrap or digit caps
- Gentle massage
- Elevation

Avoid MP hyperextension in splinting and exercises.

ADL: No use of the injured thumb in activities.
3 to 4 Weeks

Splinting: Continue with removal for exercises and hygiene.

Exercises: Each joint is moved actively into flexion as all other joints are maintained in extension. With wrist held in extension:

- Thumb IP flexion
- MP flexion

ADL: No use of the involved thumb outside of exercises.

If MP is tight in extension, remove volar strap allowing MP flexion during splint use.

If tendon adherence is limiting flexion or extension:
- Add ultrasound
- Massage over scar tissue
- Joint distraction with passive range of motion (especially into MP flexion)

5 Weeks

Splinting: Continue at night and between exercises.

Exercises:
- Add composite thumb flexion and opposition exercises.

- Thumb IP flexion with increased opposition
- Composite flexion

ADL: Begin light active use with splint applied.

If MP and IP joint are limited in flexion, begin dynamic flexion splinting with CMC in radially abducted position.
6 to 10 Weeks

Splinting: If no extensor lag discontinue

Exercises: Add active extension.

If there is an extension lag, use an IP extension splint in slight hyperextension.
Also continue with ultrasound and massage.

Gradually add resistance: Velcro board, theraband ...

ADL: Use of the thumb in all activities. Continued caution with static, resistive pinch.
Appendix I

SPLINT FABRICATION DIRECTIONS & PATTERNS
Dorsal Blocking Splint

Purpose: To position a repaired flexor tendon without stress for healing. To position the wrist and MPs in flexion for tendon protection, and the PIPs in extension to prevent flexion contractures.

Materials:
- Thermoplastic
- Self adhesive Velcro hook
- Soft strap

Fabrication:
- Cut out thermoplastic according to pattern.
- Drape over the dorsum of the forearm and hand with wrist in 20° to 30° flexion, MPs in 40° to 60° flexion, and IPs in full extension.
- Strap at the proximal forearm, wrist, hand, and fingers.

Add flexion assist:
Materials:
- Rubberband
- Self adhesive Velcro loop
- Velcro hook
- Safety Pin(s)

Fabrication: Cut a piece of self-adhesive Velcro loop the size of the fingernail and attach to the nail with super glue. Cut a piece of Velcro hook 1 cm by 2.5 cm and punch a hole in one end. Loop the rubberband through the hole and then through the safety pin attached to the wrist strap. Attach to the Velcro on the fingernail, to pull the finger into flexion.

To pull the finger into composite flexion, also thread the rubberband through another safety pin attached to the hand strap near the distal palmar crease.
**Pulley Ring**  
*(Velcro and Moleskin)*

Purpose: To protect the pulley following repair.

Materials:
- Velcro loop
- Velcro hook
- Moleskin

Fabrication:
Cut a strip of Velcro hook 5cm long and 1.5cm wide. Cut a strip of velcro loop 5cm long and 1.5cm wide. Attach them together end to end with hook facing loop. Wrap a 3 to 4cm piece of moleskin around the Velcro where it is attached. Center the moleskin over the finger where there has been a pulley repair and attach Velcro snuggly.
**Wrist Hinge Splint for Synergistic Early Active Motion**

Purpose: Allows for protected active finger flexion with synergistic wrist motion.

Materials:
- Thermoplastic
- 2 Finger rivets
- Self adhesive Velcro hook
- Soft strapping

Fabrication:
- Cut out the thermoplastic according to the pattern.
- Drape the hand piece over the dorsal hand and fingers with the MPs positioned in 60° to 70° flexion and the IPs in complete extension, curving the pieces for rivet attachment over the sides of the wrist, and flaring the center piece up.
- When cooled, punch holes for rivet attachment at the wrist joint.
- Apply lotion or massage cream to the rivet attachment pieces and position over the hand.
- Drape the forearm piece over the dorsal forearm bringing the rivet attachment pieces over those for the hand piece at the side of the wrist and flare the center piece up.
- When cooled, mark where the holes line up with the wrist joint and punch the holes in the forearm piece.
- Attach the hand piece to the forearm piece with the finger rivets.
- The center flared pieces should block the wrist at 30° extension when the wrist is brought into extension.
- Strap around the proximal forearm and wrist.
Dorsal Blocking Thumb Splint
(FPL Repair)

Purpose: To position the repaired FPL tendon without stress for healing.

Materials:
- Thermoplastic
- Self adhesive Velcro hook
- Soft strap

Fabrication:
- Cut out thermoplastic according to pattern.
- Drape over the dorsum of the forearm and hand with wrist in 20° flexion and 10° ulnar deviation, MP in 15° to 30° flexion, and IP in 0° (If zone 2 place IP in 30° to ensure excursion proximal to the pulley.)
- Strap at the proximal forearm, wrist, and hand.

Add flexion assist:
Materials:
- Rubberband
- Self adhesive Velcro loop
- Velcro hook
- Safety Pin

Fabrication: Cut a piece of self-adhesive Velcro loop the size of the thumbnail and attach to the nail with super glue. Cut a piece of Velcro hook 1.5cm by 2.5cm and punch a hole in one end. Loop the rubberband through the hole and then through the safety pin attached to the wrist strap at the base of the small finger. Attach to the Velcro on the thumbnail, to pull the thumb into flexion.
Wrist Hinge Splint for Synergistic Early Active Motion
Flexor Pollicis Longus

Purpose: Allows for protected active thumb flexion with synergistic wrist motion.

Materials:
- Thermoplastic
- 2 Finger rivets
- Self adhesive Velcro hook
- Soft strapping

Fabrication:
- Cut out the thermoplastic according to the pattern.
- Drape the hand piece over the dorsal hand and thumb, with thumb MP positioned in 15° flexion and the IP in 30° flexion curving the pieces for rivet attachment over the sides of the wrist, and flaring the center piece up.
- When cooled, punch holes for rivet attachment at the wrist joint.
- Apply lotion or massage cream to the rivet attachment pieces and position over the hand.
- Drape the forearm piece over the dorsal forearm bringing the rivet attachment pieces over the pieces from the hand piece at the side of the wrist and flare the center piece up.
- When cooled, mark where the holes line up with the wrist joint and punch the holes in the hand piece.
- Attach the hand piece to the forearm piece with the finger rivets.
- The center flared pieces should block the wrist at 30° extension when the wrist is brought into extension.
- Strap around the proximal forearm wrist and hand.
**Volar Extension Splint**

Purpose: To support the wrist and fingers in extension without stress for healing.

Materials:
- Thermoplastic
- Self-adhesive Velcro hook
- Soft Strap

Fabrication:
- Cut out thermoplastic according to pattern.
- With the hand positioned in pronation:
  - Laceration proximal to juncturae tendinum: drape over the volar hand and wrist, positioning the wrist in 30° to 40° extension, and the fingers in 0° extension.
  - Laceration distal to the juncturae tendinum: drape over the volar hand and wrist, positioning the wrist in 30° to 40° extension, the injured digit in 0° extension, and the adjacent fingers in 30° MP flexion with IPs free.
- Strap at the proximal forearm, wrist, hand, and fingers.
Dorsal Dynamic Extension Splint

Purpose: To allow protected motion to the repaired tendons, while supporting in extension.

Materials:
- Thermoplastic
- Bonding Agent
- Outrigger Wire
- Small eyehooks
- Monofilament (fishing line) or dental floss
- Rubberbands
- Small Washers
- Finger loops
- Paper clip
- Self-adhesive Velcro
- Soft Strap

Fabrication:
- Cut out thermoplastic according to the pattern (wrist cock-up).
- With arm in pronation and wrist in extension, drape the thermoplastic over the dorsum of the hand and bring the thenar piece through the webspace to the palm, positioning the wrist in 40° extension and supporting the palmar arches.
- Bend the outrigger wire so that it is positioned at a 90° pull above the PIP joints. Add a small bend to the ends of the wire to prevent them from sliding out when positioned.
- Attach the outrigger to the dorsum of the splint with a piece of thermoplastic and bonding agent.
- Bring a piece of thermoplastic around the end of the outrigger and trim.
- Screw an eye hook into the thermoplastic on the outrigger over each finger.
- Attach a paper clip hook to the dorsum of the splint at the proximal end.
- Strap at the proximal end, wrist, and hand.
- Tie a finger loop onto the end of a piece of monofilament.
- Thread the monofilament through the eyehook, and a rubberband, and tie with enough tension to maintain the finger in complete extension.
- Attach a small washer to the monofilament at the point where it will limit flexion to 30°.
- Loop the rubberband over the paper clip hook to support the finger in extension, and allow 30° of flexion in each finger.
- Repeat for all fingers.
Add a dynamic flexion component by attaching a safety pin to the palmar strap at the distal palmar crease. Super glue self-adhesive Velcro loop to the fingernail. Attach a rubberband to a piece of Velcro hook with a hole punched into the end. Attach this rubberband to the safety pin and then attach the Velcro to the fingernail to pull into composite flexion.
Hand-based Dynamic Finger Extension / Flexion Splint

Purpose: Increase finger flexion and extension.

Materials:
- Thermoplastic
- Outrigger Wire
- Bonding Agent
- Leather Loop
- 2 Rubberbands
- Safety Pin
- Self adhesive Velcro loop
- Velcro hook
- Self adhesive Velcro hook
- Soft strapping

Fabrication:
- Cut out thermoplastic according to pattern
- Form the thermoplastic over the dorsum of the hand with the MPs held in flexion. Wrap the radial bar through the webspace and into the palm.
- Cut and bend the outrigger wire so that it is positioned over the middle phalanx at a 90° angle.
- Using the bonding agent, attach the outrigger wire to the dorsum of the splint with a piece of thermoplastic.
- Loop a rubberband through the leather loop and then around the end of the outrigger. This will go around the middle phalanx and pull the PIP into extension.
- Attach the safety pin to the palmar strap at the distal palmar crease.
- Cut a piece of self adhesive Velcro loop the size of the fingernail and attach it to the fingernail with super glue.
- Cut a piece of Velcro hook 1cm by 2.5cm and punch a hole in the end.
- Loop one end of the rubberband through the Velcro hole and the other end through the safety pin. This will pull the finger into composite flexion.
ICAM (Immediate Controlled Active Motion) Splint  
(Howell, Merritt, Robinson, 2005)

Purpose: To relieve tension on the repaired tendon by positioning the involved digit in MP joint hyperextension relative to the uninvolved digits and wrist into extension.

Materials:
- Thermoplastic
- Bonding Agent
- Self-adhesive Velcro hook
- Soft Strap

Fabrication:
- Cut out thermoplastic according to the pattern (wrist cock-up).
- With forearm in pronation and wrist and fingers supported in extension, drape the thermoplastic over the dorsal wrist and hand and bring the thenar piece through the webspace to the palm, positioning the wrist in 20° to 25° extension and supporting the palmar arches.
- Cut a strip of thermoplastic with width equal to the length of the phalanx between the MP and PIP joints and the length 1½ times the distance around the MP joints.
- Position the middle of the strip underneath the proximal phalanx of the injured digit. With the injured finger positioned in slight MP hyperextension and the adjacent MPs positioned in 15° to 20° more flexion than the injured finger, wrap the piece over the dorsum of the other fingers and around to attach together at the palmar surface.
Static Thumb Extension Splint

Purpose: To position the EPL tendon without stress for healing.

Materials:
- Thermoplastic
- Self-adhesive Velcro hook
- Soft strap

Fabrication:
- Cut out thermoplastic according to pattern.
- Drape over the volar side of the hand and forearm with wrist in 20° extension, CMC between radial and palmar abduction, MP in 0° extension, and IP slightly hyperextended.
- Strap at the proximal forearm, wrist, and hand.
Dorsal Dynamic Thumb Extension Splint

Purpose: To allow motion while protecting the extensor pollicis longus tendon following repair.

Materials:
- Thermoplastic
- Bonding Agent
- Outrigger Wire
- Rubberband
- Finger Loop
- Self-adhesive Velcro
- Soft Strap

Fabrication:
- Cut the thermoplastic according to the pattern.
- Drape the thermoplastic over the dorsal radial forearm and thumb with wrist in 30° to 40° extension, CMC between radial and palmar abduction, and the MP at 0°.
- Bend the outrigger wire so it is positioned in alignment with the thumb over the distal phalanx.
- Attach the outrigger to the radial dorsal side of the splint with a piece of thermoplastic and bonding agent.
- Bring a rubberband through the loop and attach to the end of the outrigger, bringing the thumb IP into full extension.
Appendix II
HOME PROGRAM EXERCISE INSTRUCTIONS
Flexor Tendon Home Program
1 to 3 Weeks

Wear Splint at all times.
Fingers are strapped into extension unless doing exercises.

Keep hand elevated as much as possible.

Exercises: Complete 15x each, every 1 to 2 hours.
- Massage fingers to decrease edema.
- With splint applied and finger strap removed, move joints individually and into composite flexion using your other hand. Do not use your injured tendon actively.

DIP (end joint) Flexion

PIP (middle joint) Flexion

Composite (all joints together to the distal palmar crease) Flexion
Tendon Gliding Exercises

Complete each exercise 15 to 20x each, coming into complete extension between each exercise.

- Straight Fist
- Shelf
- Straight Fist
- Complete Fist
- Hook Fist
- Out
- In
- Touch thumb to each fingertip. Slide thumb down small finger.
Blocking Exercises

- Passive PIP Flexion
- Active PIP Flexion
- Passive DIP Flexion
- Active DIP Flexion
- Passive Composite Flexion

Tendon Isolation Exercises

- Superficialis Isolation
- Profundus Isolation
Flexor Tendon Early Active Home Program
Synergistic Splint and Exercises
1 to 4 Weeks

Following completion of massage and passive range of motion exercises, replace the dorsal blocking splint with the hinged splint.

Exercises: With the splint applied, complete 15 to 25 repetitions every 2 hours.

With your uninjured hand, passively bring the wrist back into extension and the fingers into full flexion into the palm.

Let go with your uninjured hand and gently hold this flexion actively for 5 seconds.

Relax the wrist into flexion while relaxing the fingers into extension.
Thumb Flexor Tendon Home Program

Wear your splint at all times. Strap the thumb into extension unless you are doing your exercises.

Keep your hand elevated as much as possible.

Exercises: Complete 15x each, every 1 to 2 hours, within the splint:
  - Massage the thumb and palm of the hand to decrease edema.
  - With the splint applied and thumb strap removed, move each joint of the thumb individually and into composite flexion using your other hand, then actively extend it back into the splint. Do not use your injured tendon actively.

IP (end joint) Joint Flexion

Composite Flexion
(all joints together toward the base of the small finger)

MP (middle joint) Joint Flexion

Hold MP joint in flexion and actively extend the IP joint.
Thumb Flexion Exercises

**Passive**

Bend IP (first) joint

Bend MP (second) joint

Bend all joints together to the base of the small finger

**Active**

Bend IP (first) joint

Bend MP (second) joint

Bend all joints together to the base of the small finger

Touch thumb to each fingertip

Slide thumb down small finger
Finger Extensor Tendon Exercises

- Hold the MP in flexion while extending the PIP.
- Raise each finger up one at a time and move side to side.
- With hand flat on the table, lift each finger up.
- With hand on the table in an arched position, lift each finger up.
- With other fingers flexed, extend each finger in isolation.
- Wrap the putty around your fingers and thumb and spread.
- Push a block (or a glass of water) across the table, using finger extension.
Passive Composite Flexion to Increase Extensor Tendon Excursion

With wrist in flexion bring all the finger joints into flexion.

Support all fingers but one on the table, then bring the isolated finger into full flexion. Repeat with each finger.
Thumb Extension Exercises

Active

Support the MP (2nd Joint) in flexion and bring the IP (1st joint) straight.

With hand flat, bring the thumb away from the hand.

With hand flat, bring thumb toward the hand.

Bring the thumb out from the index finger.

Rotate the thumb clockwise and then counterclockwise.

With hand flat, raise thumb up.

Wrap putty around the thumb and fingers and stretch.

With hand flat push with the thumb to move a weight (glass of water).
CHAPTER V

SUMMARY

The manual of tendon rehabilitation protocols in an algorithm format presented in the previous chapter is designed to provide tendon protocols that are easy to follow and that also guide the reader through the tendon rehabilitation process incorporating clinical reasoning skills. It was written following extensive literature review, which was combined with knowledge gained through clinical experience in hand patient treatment. With its use and application, it is hoped that it will give students and occupational therapists the tools to provide patients with not only the basics for adequate therapy, but also the guidance and understanding to provide excellent therapy and consequently obtain excellent therapy outcomes.

This manual will have multiple applications for use. It can be used as a teaching tool in occupational therapy departments that are teaching hand rehabilitation skills to students. It is felt that the organized format will provide for increased understanding and more time to present information in a hands-on interactive learning style.

Therapists who see hand patients clinically can also use these protocols. It is anticipated that whether therapists are new graduates, see hand patients infrequently in a setting where there are no other therapists to consult, or very experienced, they will benefit from the manual’s use. Through integration of extensive literature review and clinical experience, the manual has solid basic protocols as well as includes the protocol changes when observations varying from the usual are made. These protocols are concise
allowing for easy, rapid access to the information in a clinical setting where time may be limited. They also include drawings of the splints as well as exercises in the protocols for easy understanding. In addition to the protocols, the manual also includes appendices that provide fabrication instructions and splint patterns for all the splints referred to in the manual, and home program instruction sheets.

A limitation of this product is that currently it only contains protocols for tendon rehabilitation. It is the plan of this author to expand this project by researching and writing similar protocols for other distal upper extremity diagnoses. This expanded book could then be used in the occupational therapy educational setting as well as clinically. Following completion of these additional protocols and the accompanying splint fabrication instructions and home programs other therapists who work clinically as well teach in university programs will be consulted to obtain their opinions regarding usefulness of the protocol manual in their practice or teaching settings. If the information acquired is positive, publication of the product will be pursued, so that the manual can be used by other therapists in helping patients achieve their highest goals.
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