EARLY MOBILIZATION OF EXTENSOR TENDON LACERATIONS AT THE PROXIMAL PHALANX AND PROXIMAL INTERPHALANGEAL JOINT

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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BY

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November 1, 1990
Date

To the Dean for Graduate Studies and Research:

I am submitting herewith a thesis written by Karen Rolph-Roeming, OTR entitled "Early Mobilization of Extensor Tendon Lacerations at the Proximal Phalanx and Proximal Interphalangeal Joint". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Occupational Therapy.

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Sincere appreciation and gratitude is extended to my husband, Brant, for his enduring love and support through the duration of this study and to the Lord Jesus Christ.

I can do all things in Christ who strengthens me. (Philippians 4:13)

ABSTRACT

Early Mobilization of Extensor Tendon Lacerations at the Proximal Phalanx and PIP Joint

By Karen Rolph-Roeming, O.T.R.

December, 1990

Extensor tendon lacerations at the proximal phalanx and proximal interphalangeal joint levels have traditionally been treated with 3 to 6 weeks of immobilization following surgical repair. Expected outcomes from this treatment are limited finger flexion, extensor lags, soft tissue adhesions limiting function, joint contractures of uninvolved joints, and chronic pain problems. An alternative approach was investigated in this study. A dynamic splinting program opposite to the one used for flexor tendon repair was employed. The splint immobilizes the wrist in extension allowing active metacarpal phalangeal and interphalangeal joint motion with rubber band traction to bring the finger into full extension at rest. Eight patients with extensor tendon repairs in the proximal phalanx and proximal interphalangeal joint areas were treated. Protected motion was initiated 3 to 7 days following the surgical repair and was continued for 3 to 4 weeks. There were no tendon ruptures and all patients regained excellent flexion and strength.

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Chapter I

Introduction

Early protected mobilization for complex injuries with lacerated flexor tendons has been studied and widely accepted in the 1980's (Beasley, 1981; Cannon & Strickland, 1985; Evans, 1989; Gelberman & Woo, 1989; Peacock, 1984; Strickland, 1989). Comparatively, literature and practice involving mobilization of extensor tendon lacerations is more difficult to obtain or to find. Surgeons will readily send their patients with involved flexor tendon lacerations to the therapist 3-5 days post-operatively to begin an early mobilization program. However patients who have lacerated the extensor tendons of their hands are less likely to see a therapist until 3-5 weeks post-operatively (Beasley, 1981; Brown & Ribik, 1989) . The end result for these patients is usually extensor lag, adherent tendons, joint contractures of uninvolved joints and often chronic pain problems (Zander, 1978).

Statement of the Problem

The intricate role of extensor tendons in a well-functioning hand is frequently overlooked (Valentin, 1981). Damage or insult to the extensor system is falsely regarded as a less serious injury than an injury involving the flexor system (Evans, 1986). It is true that our hands are used more functionally in a gripping or flexed position. However, without the opening or extension of the hand it would not be possible to release an object or open the hand to grip an object. At the same time, lengthening or excursion of the extensor tendons is required to allow the hand to encircle an object (Browne & Ribik, 1989).

<u>Statement of the Purpose</u>

Balance of the two systems, the flexor system and the extensor system, is of the utmost importance for a well-functioning hand. For this reason further study and research of the extensor tendon system is necessary for acceptance of an early controlled mobilization program for extensor tendon lacerations by the medical and surgical profession to prevent extensor lag, adherent tendons, joint contractures and chronic pain problems (Zander, 1978).

This research proposes to define the rationale behind early controlled motion in the treatment of extensor tendon lacerations in areas over the proximal phalanx and proximal interphalangeal (PIP) joints of the fingers. This area is known as extensor zones III and IV. (See Appendix A.) The researcher gathered data on 8 patients to support the treatment guidelines developed for this study. (See Appendix B.) Although guidelines have been formulated for the timing of extensor tendon rehabilitation, the treating therapist must always remember that the guidelines should be altered in relation to the circumstances of each individual injury.

Hypothesis

The researcher proposed that early controlled motion initiated 3-7 days post-operatively for extensor tendon lacerations in zones III and IV can prevent adherent tendons, extensor lag, joint contractures of uninvolved joints and increase tensile strength without ruptures to allow the subject to regain functional range of motion and strength.

The Limitations

The study was limited to subjects with complete extensor tendon lacerations of one or more fingers in zones III and IV without accompanying fractures. The subjects studied had their corrective surgery performed by different surgeons. Each surgeon is engaged in individual private practice.

The study did not include tendon lacerations to the thumb. Subjects included in the study had no other pre-existing primary diagnoses and were at least 18 years of age. The study did not attempt to determine the number of surgeons who would begin sending early referrals to therapists nor the number of therapists who will follow the treatment guidelines.

Assumptions

The researcher assumed that the same surgical technique was performed on all subjects in the study and that a "functional hand" fits the description as defined in this paper. It was assumed that the subjects involved in the study followed the precautions and instructions given by the therapist.

It was assumed that the subjects included in the study were considered by the researcher to be reliable and cooperative in following through with precautions and instructions.

The Definitions of Terms

Zones III and IV. Extensor Zones III and IV of the hand are areas that have been delineated for descriptive purposes by the Committee on Tendon Injuries for the International Federation of the Society for Surgery of the Hand and which include the area over the proximal phalanx and proximal interphalangeal joint of each finger. (See Appendix A.)

Adhesion. An adhesion of the hand is the sticking together and holding fast of the repaired tendon to adjacent soft tissues during the wound healing phase (Thomas, 1973). An adhesion limits or prevents tendon glide.

Total Active Motion. Total Active Motion (TAM) is the sum of the total degrees of motion of the metacarpal phalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints of one finger.

Functional Hand. A functional hand will refer to a hand with the following qualifications and attributes achieved by the eighth week following surgical repair:

-Total Active Motion of the involved finger greater than or equal to 85% of the same finger on the uninvolved hand.

-Grip strength of the involved hand is greater than or equal to 85% of the uninvolved hand.

Chapter II

The Review of the Related Literature

A review of the literature reveals the practice of early controlled mobilization for flexor tendon lacerations following surgical repair (Beasley, 1981; Cannon & Strickland, 1985; Duran, Houser, Coleman & Stove 1978; Evans, 1986; Gelberman & Woo, 1989; Lister, Kleinert, Kutz & Atasoy, 1977; Strickland, 1989; Weeks & Wrey, 1978). Relatively little attention has been given to early mobilization for extensor tendon injuries until the last 3-5 years. Extensor tendon lacerations continue to be treated conservatively immobilizing the repair for a period of 3-6 weeks following surgical repair (Browne & Ribik, 1989; Evans & Burkhalter, 1986; Lee, 1978).

It is an accepted belief among hand specialists that a ruptured tendon repair is a surgeon's or a therapist's nightmare. If a tendon repair ruptures, a second surgery is required and the rehabilitation process must be started again from the beginning (Beasley,1981). With a second repair, the tendon is not as strong and often the ruptured ends must be shortened to reach viable tendon tissue for an adequate repair. The risk of turning nightmare into reality has been avoided by immobilizing tendon repairs in a position providing the least amount of stress to the healing tendons for at least three weeks. The typical result from this treatment is a stiff, tenodesed, poorly functioning hand (Browne, 1989). In contrast, the practice of establishing early motion for complex injuries can be found in the literature and is recommended by many authors (Beasley, 1978; Burkhalter, 1978; Madden, 1978; Wilson & Carter, 1978). More recent study has focused on early mobilization for repaired extensor tendons, specifically in zones V and VI (Browne & Ribik, 1989; Evans, 1986). (See Appendix A.)

Physiology and Glide

Glide is the ability of a tissue to move through layers of displaceable tissue such as skin, muscles, aponeuroses and tendon sheaths. Amplitude is the actual excursion or distance that the tendon or muscle travels in order to extend the joint. Glide is dependent on the contraction of the muscle, freedom from adhesions and the anatomic placement of pulleys and joints. Dr. Paul Brand (1985) completed extensive studies to determine the amount of tendon glide or amplitude available at each joint. With full PIP joint flexion and extension in the normal hand there are only three millimeters of tendon glide available at the PIP joint. This compares to 16 millimeters available at the MCP joint with full motion. (See Table 1.) Duran and Houser (1975) suggested that 3 to 5 mm of passive glide will provide adequate tendon excursion to prevent fixed adhesions.

Table 1

Extensor Tendon Excursion Available

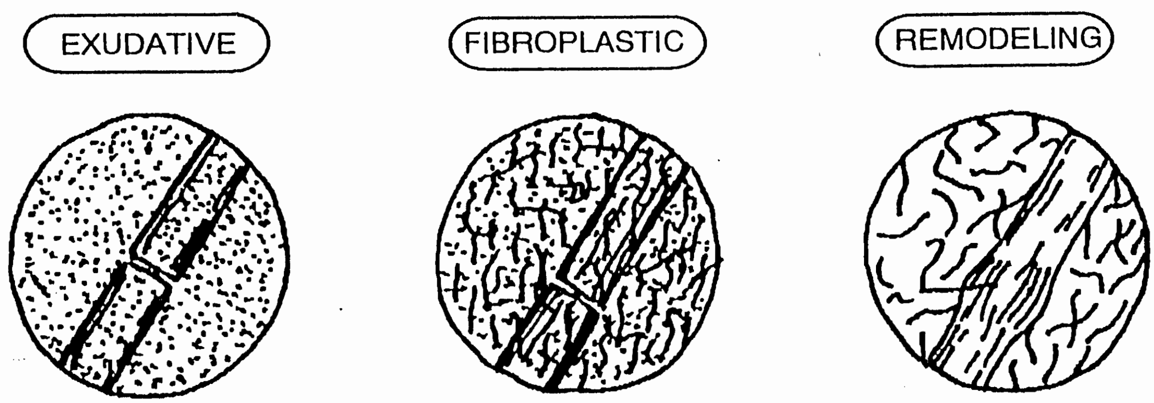
Finger	Amount of excursion			
	Wrist	MCP	PIP	DIP
Index	38 mm	15 mm	2 mm	0
Middle	42 mm	16 mm	3 mm	0
Ring	39 mm	11 mm	3 mm	0
Little	20 mm	12 mm	2 mm	0

Note. Adapted from "Therapeutic management of Extensor Tendon Injuries" by R. B. Evans, 1986, "Hand Clinics", 2, p. 159.

Wound Healing

Wound healing is a complex phenomenon. It has been characterized by three phases. (See Figure 1.) The first is the inflammatory or exudative phase. The inflammatory process occurs immediately post-injury and lasts approximately 24 hours. It is characterized by initial scar tissue formation, vascular changes, migration of leukocytes to the injury site and phagocytosis of foreign substances. The inflammatory elements including leukocytes, phagocytes and lymph leakage leave the vascular system and accumulate in the wound. These elements fill all parts of the wound from the cut ends of the tendon, the tendon and adjacent periosteum, the fixed tendon sheath, the mobile subcutaneous tissues and any other tissues or structures involved with the injury. Edema is present from blood and lymph leakage into the area. Within 24 hours the appearance of capillary budding with surface granulation is present as the body begins to rebuild and repair itself (Bryant, 1978; Hunter & Mackin, 1978; Madden, 1978).

Figure 1: Three stages of wound healing.



The second phase is the fibroplastic stage. It is marked by the migration of fibroblasts to the site of injury. This migration typically begins 24 hours post-injury and can continue for two to four weeks. The fibroblasts enter the entire cavity expelling collagen molecules. These collagen molecules are brought together to form collagen fibrils. The fibrils link all parts of the cavity in a three dimensional network of collagen fibers with random orientation. Initially, these bonds are weak but later mature into strong flexible fibers. These bonds are the same between the ends of the repaired tendons as between the tendons and any other adjacent tissues or structures involved in the injury. However, differential wound healing is essential for functional recovery in the hand following tendon injuries. Strength is needed between severed tendon ends to transmit muscle power through or at the injury site. At the same time, weaker bonds of healing between the tendon and the adjacent tissues is needed to prevent fixed adhesions and prevent inhibition of tendon glide. During this phase tensile strengthening of the wound is most rapid but the scar remains easily modified (Bryant,1978).

A change in the size, shape, color, texture and strength of the scar tissue marks the maturation stage. This is the third phase of wound healing. These changes are very slow and not recognizable over short periods of time. The collagen fibers become very organized. This organization limits the ability for modification and stretching. The presence of myofibroblasts causes contracture and shrinking of scar further limiting modification. This maturation stage can continue six months to years (Beasley, 1981; Madden, 1978).

During early phases of scar tissue development, scar rapidly encloses all injured tissues into one strong mass. This becomes very unsatisfactory in the hand when mobile structures are bound to immobile units thus limiting function. After tendon laceration and repair, tendon ends must be linked together by strong scar tissue, but the character of scar joining tendon to surrounding immobilized structures must be altered to permit tendon gliding and to reestablish satisfactory function. This is differential wound healing (Madden, 1978).

Collagen Formation

The architecture of scar tissue is directly related to the resultant motion and function. Ideally, reorganization of the collagen between the repaired tendon ends into completely polarized bundles with great strength is desirable. The collagen should be inelastic and strong like normal tendon. At the same time it is desirable for the collagen between the tendon and the adjacent tissues to be arranged in random orientation and highly elastic or mobile. Under microscopic examination, differences can be noted between the architecture of scar where the tendon gliding mechanism is restored, such as with an early mobilization program, versus the architecture of scar where tendons fail to regain gliding mobility from prolonged immobilization. Where gliding is restored, scar collagen has been arranged between tendon ends in parallel bundles resembling normal tendons. This parallel orientation enforces a strong bond between tendon ends with the capability for transmitting powerful longitudinal forces. In addition, collagen fibers adjacent to the healing tendons enlarge and develop randomly but loosely. This promotes continued vascularity and vessel integrity. In comparison, where gliding is not restored, the scar tissue has organized into firm collagenous bundles adhering to fixed surrounding tissues preventing tendon glide (Beasley, 1981; Madden, 1978; Peacock, 1981).

The healing and collagen formation process can not be controlled but it can be influenced. First, the less collagen mass in the wound the more rapid and functionally satisfying remodeling is expected. Careful atraumatic surgical technique can minimize further tissue injury and collagen deposition. Secondly, existing collagen tissues guide remodeling of new collagen toward inelastic parallel bundles. The surgeon can excise any existing dense scar in areas of tendon repair as thoroughly as possible during the surgical repair. Finally, experimental and clinical evidence has indicated that longitudinal stresses can play an important role in scar tissue development and remodeling. The controlled use of early mobilization to stress the scar tissue following tendon injury can therefore be used to encourage parallel line-up of collagen fibers with the repaired tendons. This promotes gliding while improving tensile strength (Beasley, 1981; Madden, 1978; Peacock, 1981).

These factors form the basis for the trend toward carefully timed post-operative exercises. If the stress is applied too early or too vigorously the inflammatory reaction can be increased thereby promoting increased collagen mass in the wound or rupture to the tendon repair. In summary, early motion seems to guide the collagen orientation toward elongated adhesions of good mobility.

Chronic Pain

Early mobilization not only assists with parallel formation of scar and tensile strengthening of the repair, but also prevents joint stiffness of both involved and uninvolved joints. Re-establishment of joint movement with early motion should be a constant concern in treating any injury to the hand. Ideally, this should be initiated by one week post-injury or post-operatively. In addition, clinical experience and review of the literature indicates a rare occurrence of the chronic pain problems confronted with cases of prolonged immobilization when early motion post-injury is utilized (Beasley, 1978).

Nutrition and Vascularization

A severed tendon with an interrupted blood supply can not heal if it is isolated from contact with other adjacent tissues. If there has been a disruption in the vascular supply to the tendon a slower rate of healing will be expected. There are four sources for tendon vascularization or nutrition. First, there are a number of small vessels entering the peritenon from surrounding soft tissues where the tendon lies. Second, there is a mobile system similar to the mesentery of the intestines known as the digital vinculae. The third and fourth sources provide a minimal contribution. They include the vessels entering at the musculotendinous junction and the vessels entering from the bone at the tendon insertion (Smith and Bellinger, 1981; Verdan, 1981).

<u>Rationale</u>

The literature indicates that treatment of extensor tendon lacerations in zones III and IV typically includes 3 to 6 weeks of immobilization. The outcome for this treatment includes extensor lag, adherent tendons, joint contractures of uninvolved joints and often chronic pain problems. A second treatment advocated in the literature for this level of injury is to splint the MCP and PIP joints in full extension allowing active flexion and extension of the DIP joint (Valentin, 1981). If the PIP joint is held in extension during active DIP joint motion, the lateral bands will displace the tension or glide away from the extensor tendon. This causes a resulting loss of tension and glide in the central slip inserted on the base of the middle phalanx or at the injury and repair site. (See Appendix D.) In both of these treatment situations, adhesions can develop frequently requiring a subsequent tenolysis. The tenolysis is then followed by early mobilization (Beasley, 1981). The second surgery, tenolysis, requires an additional phase of treatment prolonging the total rehabilitation process with less satisfying results.

Edema. Chronic edema has been associated with prolonged immobilization following injury. The pumping action required with early motion assists with edema reduction when combined with elevation and unprotected movement of uninvolved joints in the upper extremity (Beasley, 1987; Hunter and Mackin, 1987).

Tissue integrity. Tissue integrity can be maintained with early protected mobilization. The MCP joint collateral ligament is taut in extension but stretched with MCP joint flexion. The involved finger is frequently immobilized with the MCP joint in full extension to avoid tension on the repaired tendon. This allows tightening of the collateral ligament with subsequent loss of MCP joint flexion. If the involved finger is immobilized in slight flexion to prevent tightening of the collateral ligaments, the expected outcome is extensor lag due to healing of the relatively weak extensor tendon in a stretched position. The MCP joint collateral ligament length can be preserved without promoting extensor tendon lag if the finger rests in full extension during both static and dynamic splinting allowing protected active flexion in the dynamic splint.

The length of the intrinsic muscles of the hand, both interossei and lumbricals, must also be maintained. The intrinsic muscles are contracted when the MCP joints are flexed with the PIP and DIP joints extended. They are stretched when the MCP joints are extended with the PIP and DIP joints flexed. Tightness of the intrinsic muscles limits strength and interrupts functional cylindrical grasping. If the wrist and MCP joints are extended to protect the repaired tendon, gentle passive combined PIP and DIP flexion can be utilized to maintain intrinsic muscle length.

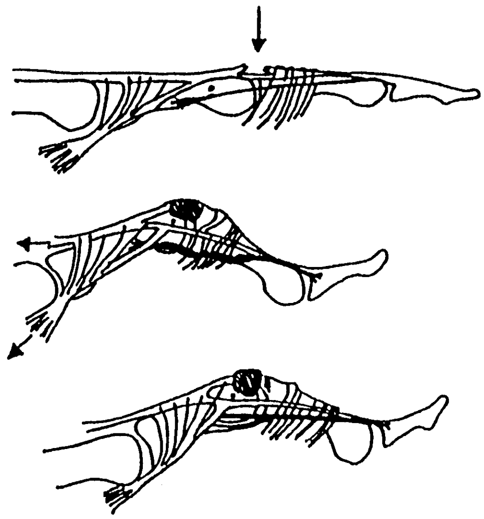
Anatomy. The extensor tendons are in close proximity to the bones in extensor zones III and IV. This close proximity increases the probability of developing adhesions of mobile tendon to fixed bone. As discussed previously, adhesions of mobile tissue to immobile tissue inhibits glide. Without tendon glide the finger cannot be flexed into a gripping position to pick-up or hold objects nor can the finger be extended to open the hand. Examination of surface anatomy reveals a lack of soft or mobile tissue over the proximal phalanx in comparison to the amount of soft tissue over the metacarpals. This is in evidence by the amount of tissue that can be pinched and lifted up in the two different areas. Soft tissue adhesions will stretch as contrasted to adhesions to bone. With the deficient amount of soft tissue and close proximity of tendon to bone, early mobilization is important to avoid debilitating functional limitations in the injured hand (Zancoli, 1982).

Collagen remodeling. As previously stated, restoration of the tendon gliding function is desirable to alter the architecture of the scar. Longitudinal stresses present with restoration of glide encourage parallel organization of the collagen or scar to increase tendon excursion and tendon strength. Tensile strength is increased when subjected to stress. Caution is necessary to prevent over stressing with resultant rupture of the repair (Madden, 1990).

Success with early controlled motion. Successful treatment of flexor tendons in zone II and extensor tendons in zones V and VI using early controlled mobilization have been well documented (Duran et al., 1978; Evans, 1986; Lister, 1977; Nissenbaum,1978; Strickland, 1989). (See Appendix C.) This involves active contraction of the antagonist muscle with reciprocal relaxation of the agonist.

Summary. Extensor tendon injuries occurring over the PIP joint or proximal phalanx, zones III and IV, are critical injuries due to the complex interaction of the

Figure 2. Development of boutonniere deformity.



A. Injury disrupts insertion of the central slip at the base of the middle phalanx. B. The Middle phalanx is pulled into flexion by the flexor digitorum sublimis. The lateral bands displace volar to the joint axis becoming joint flexors. C. Tightening of the volar plate ligaments and retinacular ligaments with shortening of the extensor tendon (Rosenthal, 1990).

extensor mechanism (Lee, 1978; Silverman, 1989). (See Appendix D.) The relationship of the central slip and lateral bands with the joint axis of motion must be considered to avoid the development of a boutonniere deformity (Rosenthal, 1987). It can be assumed that joint stiffness and tendon adhesions must be avoided in zones III and IV of the extensor tendons as in zones V and VI for extensor tendons and zone II for flexor tendons. This indicates that similar treatment of early mobilization should be applied. When working with injury to extensor tendons in zones III

and IV one must also guard against development of boutonniere deformities (Browne & Ribik, 1989; Tubiana, 1986). (See Figure 2.)

same success.

Data was gathered on 8 subjects to support the efficacy of the treatment guidelines and to support the use of the early controlled mobilization of extensor tendon lacerations in zones III and IV. The treatment guidelines that have been developed were followed for the study. The researcher believes that the developed guidelines will allow other hand therapists with a functional knowledge of extensor tendons to duplicate the proposed early controlled mobilization treatment for extensor tendon lacerations.

<u>Subjects</u>

The researcher selected 8 qualified patients with 8 lacerated tendons who met the guidelines for the proposed study. Each patient signed a "Consent to Treat" form before treatment was initiated. (See Appendix E.) Each patient was treated following the strictures defined in the treatment guidelines for early controlled mobilization of extensor tendon lacerations in zones III and IV. (See Appendix B.) Data collection was gathered by the researcher, who is employed as an occupational therapist at the Fort Worth Hand Rehabilitation Center, following the data collection form. (See Appendix F.) The subjects were treated by the researcher at the Center once or twice weekly for a period of 6 to 8 weeks.

Procedure

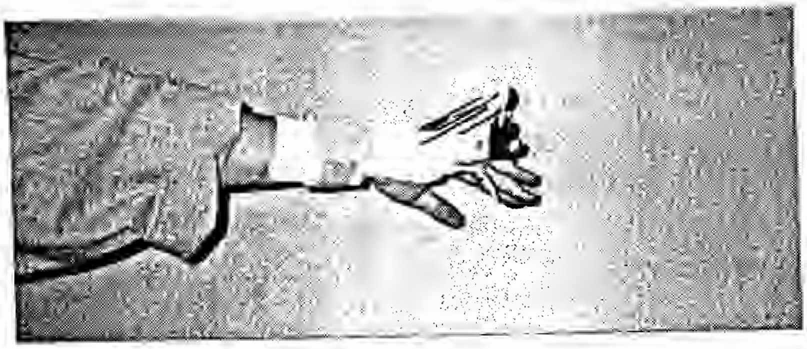
Therapeutic treatment began with selection of qualified patients. Patients chosen had lacerations of extensor tendons in zones III and IV, had stable osseous structures and were considered to be cooperative and reliable. They were initially treated at the hand center 3 to 7 days following surgical tendon repair. Initiating therapy prior to 3 days following surgery was avoided due to the need for bulky compressive dressings from fingertip to the upper forearm to minimize the inflammatory response (Hunter and Mackin, 1990). At the first visit, the post-operative bulky dressings were removed with the hand protected in an extended and elevated position. Appropriate wound care was performed including cleansing with diluted peroxide, applying antibiotic ointment and light dressings. Light dressings were used to allow the desired controlled mobilization. Each patient was instructed in basic anatomy, precautions and the goals of rehabilitation.

The anatomy of the extensor mechanism is complex but can be explained in understandable terms to the patients. Instruction included a verbal and visual description of the body's response to injury with the formation of scar tissue. A hand model with a mobile tendon was used. Emphasis was placed on the need for strong scar tissue to develop between the repaired tendon ends but loose and weak between the mobile tendon and other surrounding soft and immobile tissues. Each patient was cautioned against active extension of the involved finger as well as gripping or lifting with the involved hand to avoid risk of tendon rupture and increased inflammatory response. The goal of therapeutic intervention was to promote tendon healing while maintaining tendon glide to regain maximal tendon excursion and hand function.

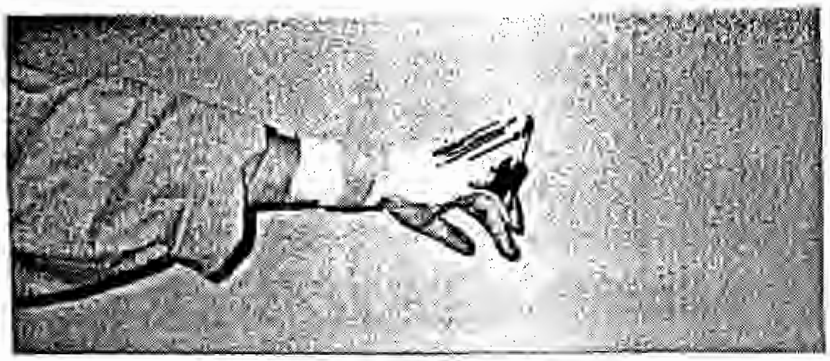
A thermoplastic dynamic forearm based gutter splint was fabricated to immobilize the wrist in 35 to 40 degrees of extension. Dynamic rubber band traction was applied to rest the MCP, PIP and DIP joints at zero degrees. A volar block allowed 50 to 60 degrees of active flexion at the PIP joint and 30 to 40 degrees of active flexion at the MCP joint. (See figure 3.) Immobilizing the wrist in extension provides extra slack in the extensor muscle-tendon unit to avoid stress on the repair site. MCP joint motion is desirable to maintain collateral ligament integrity. PIP joint motion is essential to maintain glide of the healing tendon through the sagittal bands and dorsal fibers of the transverse retinacular ligament, stretch adhesions as they form and maintain integrity of the extensor mechanism. (See Appendix D.) The subject was instructed to flex the involved MCP and PIP joints allowing the finger to touch the volar block then relax allowing the rubber band to return

Figure 3. Dynamic and static splints.

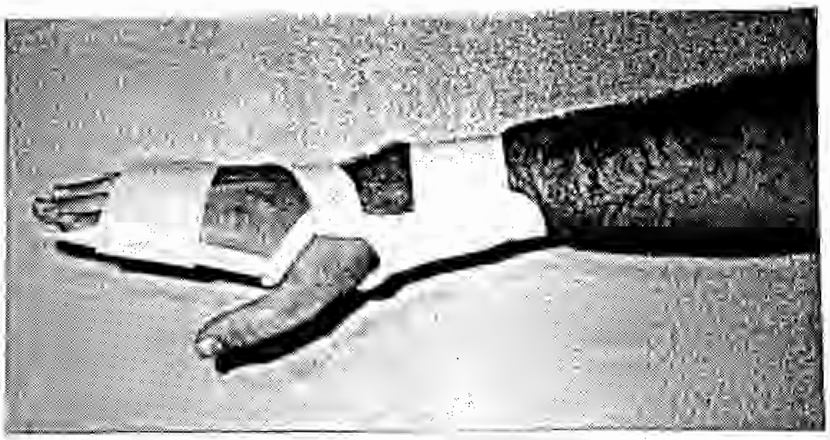
A.



B.



C.



A. Dynamic forearm based ulnar gutter splint for lacerated extensor tendon to little finger. Rubber band traction holds little finger in full extension when at rest. B. Active flexion of the injured little finger within the confines of the splint. C. Static extension splint worn at night. Positions the wrist in 30 to 40 degrees of extension with the MCP, PIP and DIP joints in neutral.

the finger to full extension. Ideally, these exercises were repeated 5 to 10 repetitions every hour during the day. During structured therapy sessions, careful individual active flexion exercises were completed for each joint while the others were maintained in full extension. All motion was slow and gentle.

If the patient demonstrated excessive difficulty or discomfort with flexion to the limits of the volar block, healing of the injured tendon with development of adhesive scar was suspected. These patients were pushed harder to improve finger flexion. However, if the patient demonstrated no difficulty or discomfort with flexion to the volar block limits in the splint, slow or weak healing was suspected. In this case, the researcher suspected possible weak scar formation between tendon ends as well. These patients were progressed more gradually with smaller increments of increased flexion limits.

A static thermoplastic volar forearm based splint was fabricated to be worn at night when sleeping. It positioned the wrist in 30 to 40 degrees of extension with the MCP, PIP and DIP joints in neutral or zero degrees of extension. (See figure 3.) Both splints were monitored closely to maintain resting finger position in neutral to prevent lengthening of the healing extensor muscle-tendon unit or attenuation of the healing scar between tendon ends. Either of these situations can cause extension lag and interfere with hand function.

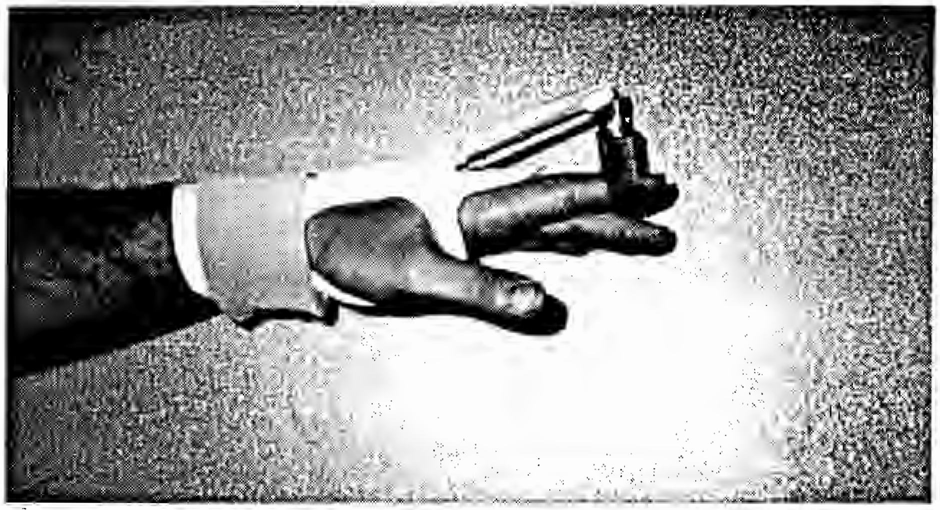
This program was continued for 3 to 4 weeks with dynamic splinting during the day and static extension splinting at night. Flexion limits in the dynamic splint were gradually increased as indicated by the signs of healing as mentioned above.

By the third to fourth week following surgery the volar block was removed from the dynamic splint allowing unlimited flexion. (See figure 4.) The rubber band traction continued to passively extend the injured finger at rest. Active extension was initially introduced while the patient was at the hand center. The injured hand was placed in hot moist packs to soften the scar and soft tissue to ease tendon glide with minimal stress and strain (Michlovitz, 1986). The patients were instructed to continue dynamic splinting during the day for one more week removing the splint 3 to 5 times each day to complete the controlled active extension and flexion exercises as practiced at the hand center. Static extension splinting at night was continued for 4 to 6 more weeks to discourage extension lag.

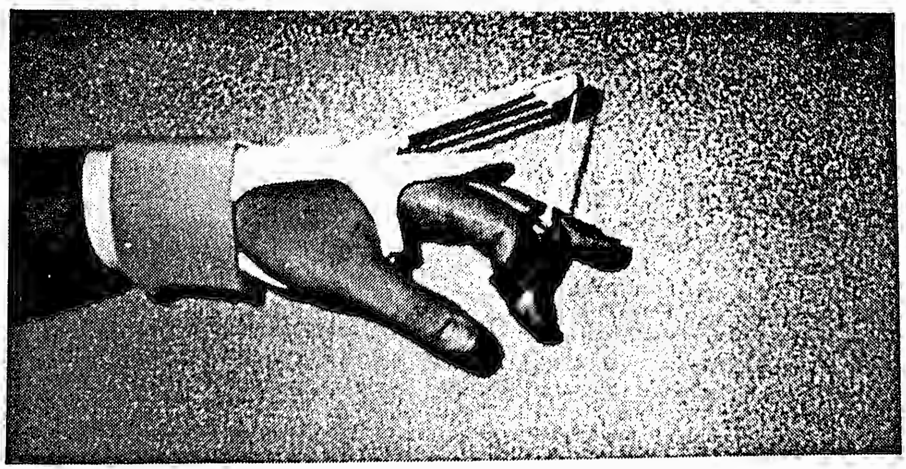
Between 4 to 6 weeks following surgery the dynamic splint was discontinued. Active finger extension was continued with gradually increasing resistance applied. Progressive strengthening for both flexion and extension was

Figure 4. Dynamic splint with volar block removed.

A.



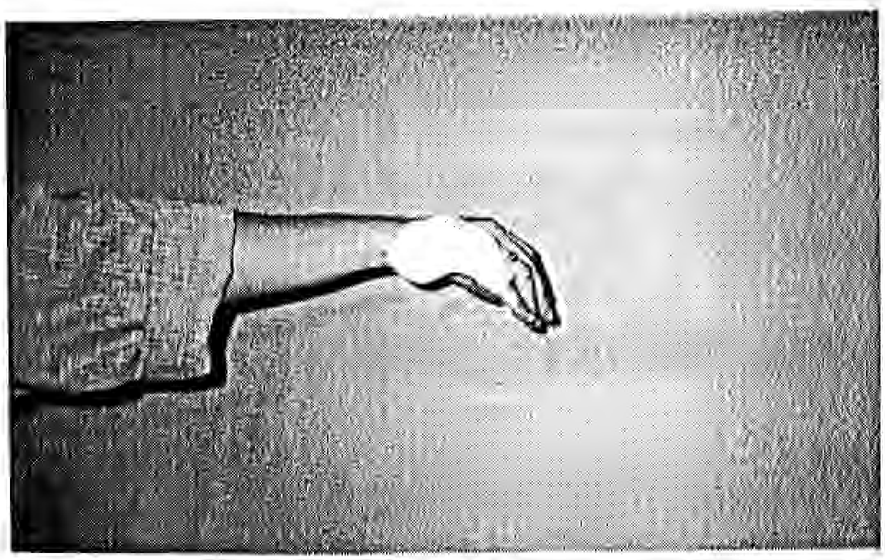
B.



Dynamic forearm based radial gutter splint with volar block removed for lacerated extensor tendon to index finger. A. Rubber band traction holds little finger in full extension when at rest. B. Active flexion of the injured index finger without limitation of the volar block.

initiated. Light resistive theraputty was used to assist with improving flexion and strength of the injured finger. Due to close monitoring of the patients by the researcher to assure accurate fit and mobilization in the splints, no deformities developed to require corrective splinting. In two cases, the patients were fit with protective splints to be worn when working until they were able to make full fists without discomfort. The work splint prevented the patient from making a forced or tight fist and blocked the finger from full extension. (See Figure 5.) These two patients were employed in jobs requiring heavy lifting and tight grasping of tools. Precautions were removed from all patients when they were able to make a full comfortable fist with reciprocal full extension.

Figure 5. Protective work splint.



Data Collection

The data for this research includes two sets of primary data. The first set of data is the AROM charts including MCP, PIP, and DIP joint AROM and TAM measured in degrees. The researcher used the same type of goniometer for all AROM measurements. Range of motion measurements were taken at a minimum of 4, 6 and 8 week intervals. The second set of data is the grip strength chart measured in pounds of pressure using the Jamar dynamometer. The Jamar dynamometer was used in handle position number two to evaluate grip strength for all patients included in the study. Grip strength measurements were taken following the standardized instructions described by Mathiowetz, Weber, Volland & Kashman (1984). The grip strength measurements were completed by the eighth week following surgical repair. (See Appendix F.)

Data from patients who had extensor tendon lacerations in zones III and IV without other complications were used in the study. In addition, only the patients who were seen by the researcher at the Center within the first week following surgical repair were used in the study.

For this study a functional hand was defined by using the subject's uninvolved hand as the comparison of "normal" for each individual. The researcher considered using the estimated AROM averages developed by the American Academy of

Orthopaedic Surgeons. (See Appendix G.) However, from clinical experience, the researcher realized the variance of each individual from the Academy's estimated average. This indicates that comparison to the uninvolved hand is more descriptive of individual return to "normal" function. This rationale was also used for the grip strength measurement and comparison. Instead of using the "norms" developed from Mathiowetz et al (1985), each patient's involved hand was compared to the uninvolved hand. (See Appendix H.)

Chapter IV

Results and Discussion

Dynamic splinting was continued for 3 to 4 weeks. The first week after dynamic splinting was stopped, active motion with light resistance was initiated. This was followed by 1 to 2 weeks of active motion with moderate resistance and finally 1 to 2 weeks of motion with maximum resistance. Therapy was completed by the end of 8 weeks.

There were no tendon ruptures in any of the 8 patients treated with early motion. Total active motion (TAM) of the injured finger was 96 percent or better of the uninjured contralateral finger. Total active motion of the injured finger for 4 out of the 8 patients was 100 percent or greater than the uninjured contralateral finger. Minimal extension lags of 4 degrees were present in 2 out of the eight patients. This lag was attributed to some residual swelling. All patients were able to make a complete fist with the wrist in functional position. All patients passed the functional test of range of motion where the TAM of the involved finger was 85 percent greater than the same finger on the uninvolved hand. (See Table 2.)

Restoration of grip strength for all 8 patients was 93 percent or greater in comparison to the uninvolved hand.

Table 2.

Percent of TAM Regained Comparing Involved to Uninvolved

Subject	Percent TAM
C.A.	101%
J.H.	98%
M.H.	100%
A.K.	105%
G.P.	97%
C.P.	102%
T.S.	96%
F.W.	100%

Four of the eight patients regained greater than 100 percent grip strength in the injured hand in comparison to the uninjured hand. All 8 patients passed the functional test of strength where the grip strength of the involved hand was 85 percent greater than the uninvolved hand. (See Table 3.)

All patients returned to their previous type of vocational and avocational activities following treatment. The earliest return to work was at 1 day following surgery. The latest return to work was at 8 weeks. No secondary tendon surgery was required for any of these patients treated by early motion. (See Table 4.)

Table 3.

Percent of Grip Strength Regained in Comparison to Contralateral Hand

Subject	Percent Grip Strength
C.A.	98%
J.H.	95%
M.H.	93%
A.K.	101%
G.P.	115%
C.P.	104%
T.S.	114%
F.W.	98%

Table 4.

Results

Number tendon ruptures	0 of 8
Secondary tenolysis	0 of 8
Full fist flexion	8 of 8
Functional grip strength	8 of 8
Return to work	Aver. 3-4 wk

Chapter V

Conclusion and Recommendations

Early protected mobilization for extensor tendon lacerations is an area that has not been developed and accepted in practice. The results achieved with this treatment as outlined in the study are very encouraging. It is understood that this is a biased study because the selection process determining the type of treatment and splint was not randomized. The assessment of patient cooperation was the primary factor used to determine selection for inclusion in the study. The selection process was obviously related to the excellent results achieved in the early motion group. The closely supervised therapy given to the early mobilized group of patients also played an important role in their final functional outcome.

In contrast, there were 3 patients treated by the same researcher before the study was initiated. They were immobilized for a period of 3 to 6 weeks using static splinting. Their results were not as impressive as the group treated with early mobilization. (See table 5.) Total active motion of the injured finger was 81 to 92 percent of the contralateral uninjured finger. These immobilized patients were unable to make complete fists and complained of residual pain during attempts with tight flexion. Restoration of grip strength was 11 to 92 percent in comparison to the uninvolved hand. (See appendix I.) A second and third tendon surgery was required for 1 of the immobilized patients. All three patients complained of continued stiffness in the involved DIP, PIP and MCP joints. Therapy continued from 9 to 14 weeks. One of the three patients was unable to return to his previous employment duties and eventually found another job.

Table 5.

Comparison of Early Motion Group to Immobilized Group

	Early Motion	Immobilized
Number of subjects	8	3
Aver. weeks treatment	8	11.6
Average % TAM	99.9%	85%
Average % strength	102%	49.7%
% repeat surgery	0%	33%
% return to work	100%	66%
% with residual pain	0%	66%

Static splinting has been the traditional choice of treatment following extensor tendon repair as confirmed by the literature review. The researcher believes that a superior result was achieved by the early controlled motion group than by the static splinted group. Since there were no tendon ruptures and all patients obtained excellent extension, flexion and strength, it is concluded that this early motion treatment can be considered as a safe method when supervised by a competent hand therapist.

The researcher believes this treatment is appropriate for extensor tendon lacerations where poor results might be anticipated. These circumstances might include multiple tendon lacerations, lacerations involving the proximal phalangeal periosteum or proximal interphalangeal joint, or patients with a history of excessive scarring. The techniques can be modified to meet requirements of more involved injuries including metacarpal or phalangeal fractures with or without multiple soft tissue injuries.

Success of this treatment method depends on early referral post-operatively, a cooperative patient and an experienced hand therapist with thorough knowledge in wound healing and extensor tendon anatomy, physiology and nutrition. A comparison study with randomized placement into early motion and immobilization groups is necessary before statistically significant improved results with early motion treatment can be claimed. The results of this study coincide with research documented in the literature for early mobilization of lacerations at the metacarpal and metacarpal phalangeal joints, zones V and VI. Further investigations might include early mobilization for the non-compliant patients or implementation of the guidelines by an inexperienced hand therapist to determine whether or not these factors influence the success of the treatment. This treatment technique might also be adapted for extensor tendon lacerations to the thumb. The approach of early controlled mobilization appears to be a viable option for the treatment of extensor tendon injuries.

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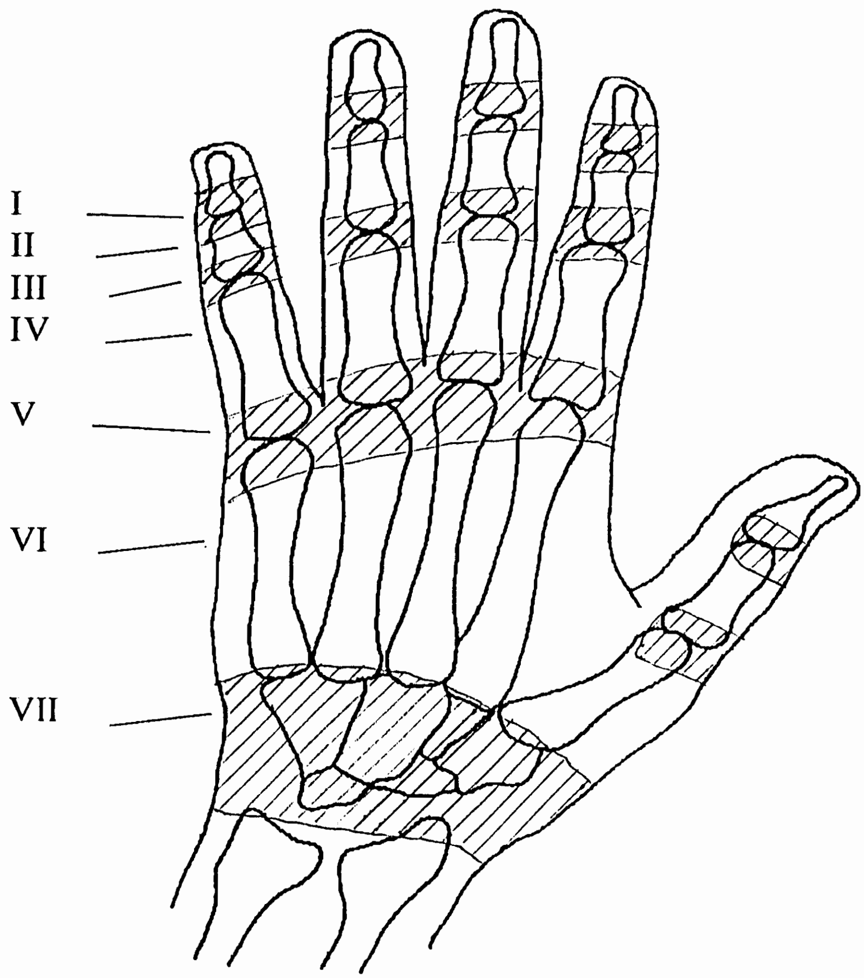
APPENDIX A

Extensor Tendon Zones

Extensor Tendon Zones



Extensor tendon injuries are frequently described according to location. The location is often noted by referring to "zones". This figure illustrates extensor tendon zones as defined by the committee on tendon injuries for the International Federation for Surgery of the Hand (Kleinert, 1981).

APPENDIX B

Treatment Guidelines for Early Mobilization Following Extensor Tendon Lacerations

TREATMENT GUIDELINES

Early motion is recommended for tendon lacerations in extensor zones III & IV when osseous structures are stable and only with cooperative patients.

<u>3-7 days post-op</u>:

*Bulky dressings removed with hand protected in extended position
*Wound care
*Dressings reapplied
*Patient instructed in edema control techniques of elevation & shoulder / elbow AROM
*Dynamic forearm based splint is fabricated
-wrist immobilized in 35°-40° extension
-dynamic traction rests MCP, PIP & DIP joints at 0°
-volar block allows 50°-60° active flexion at the PIP joint
-volar block allows 30°-40° active flexion at the MCP joint
*Patient instructed to flex PIP joint allowing finger to touch volar block then relax allowing rubber band to return finger to full extension
*Ideally exercise repeated 5-10 repetitions every hour during day
*During structured therapy sessions, careful individual active flexion exercises completed for each joint while others maintained in full extension
*Static forearm, based splint fabricated for night use with MCP, PIP & DIP joints immobilized at 0°

This program is continued for 3-4 weeks with gradually increased flexion limits in the dynamic splint as indicated.

<u>21-27 days post-op</u>:

*Volar block removed allowing unlimited flexion
*Active extension is initiated
*Continue dynamic splinting during day for 1 more week
*Continue static splinting at night 4-6 more weeks

<u>28 days post-op</u>:

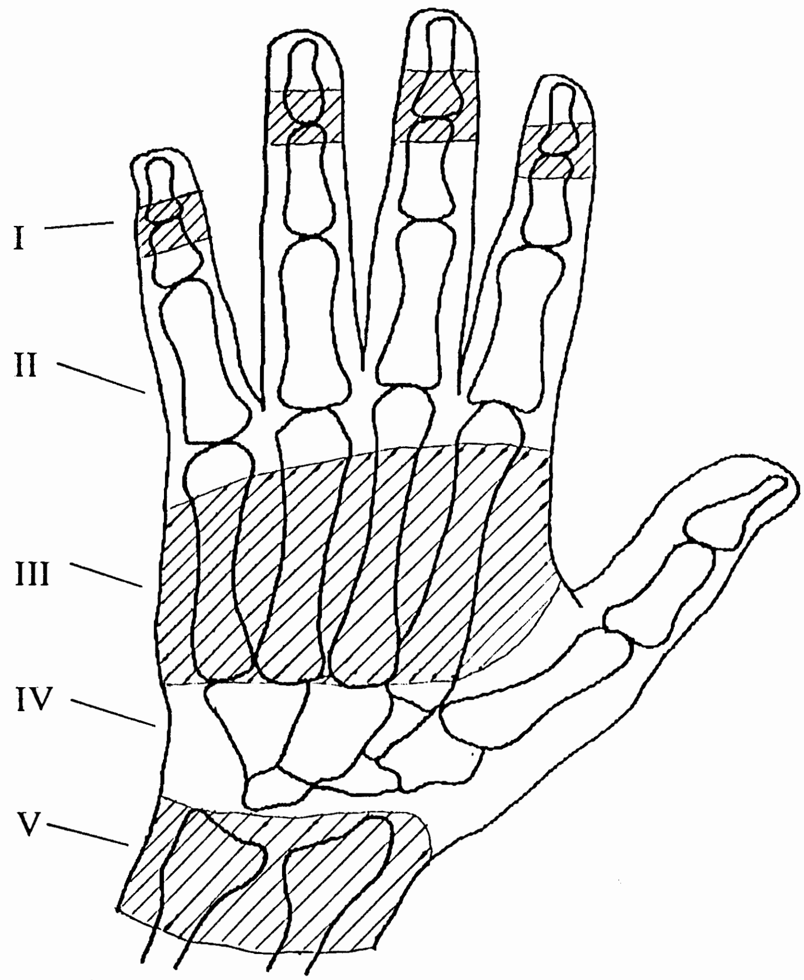
*Discontinue dynamic splint
*Continue active extension
*Begin progressive strengthening for flexion & extension
*Splint as needed to
-correct deformity or extensor lag
-protect repair for daily functional/vocational needs

Precautions are removed when the patient can make a comfortable full fist.

APPENDIX C

Flexor Tendon Zones

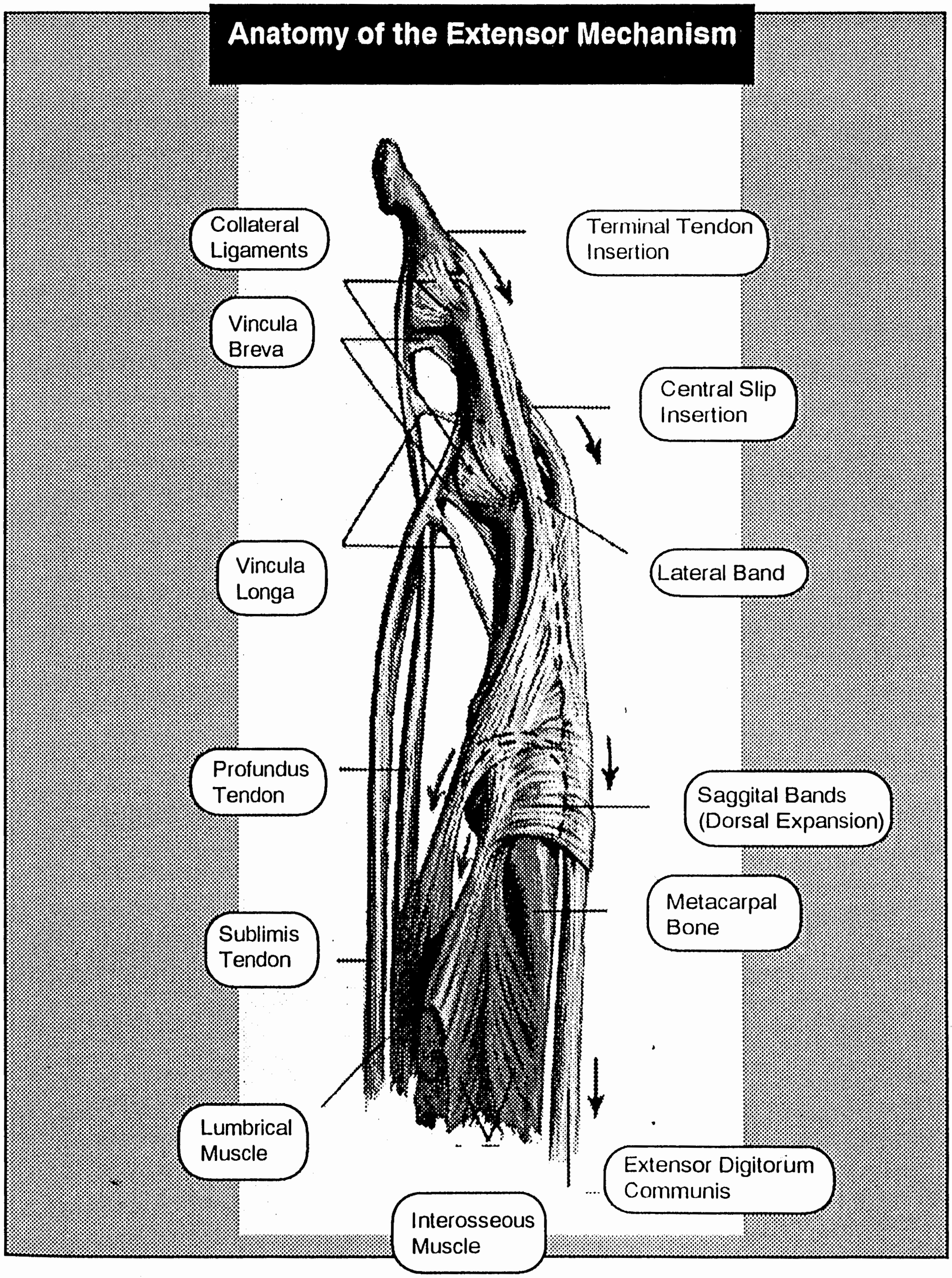
Flexor Tendon Zones



Flexor tendon injuries are frequently described according to location. The location is often noted by referring to "zones". This figure illustrates flexor tendon zones as defined by the committee on tendon injuries for the International Federation for Surgery of the Hand (Kleinert, 1981).

APPENDIX D

Anatomy of the Extensor Mechanism


Anatomy of the Extensor Mechanism
Collateral Ligaments
Terminal Tendon Insertion
Vincula Breva
Central Slip Insertion
Vincula Longa
Lateral Band
Profundus Tendon
Saggital Bands (Dorsal Expansion)
Metacarpal Bone
Sublimis Tendon
Lumbrical Muscle
Extensor Digitorum Communis
Interosseous Muscle

APPENDIX E

Patient Information Sheet

Consent to Treat

Patient Information Sheet III

CONSENT TO TREAT

Permission is granted to Julie Amendola, O.T.R./L. and the staff of the Fort worth Hand Rehabilitation Center to Perform hand therapy treatment and photograph as deemed necessary by the licensed therapists and/or prescribed by the physician.

Patient's Signature Date

APPENDIX F

Extensor Tendon Data Sheet

for Patients Treated with Early Motion

EXTENSOR TENDON DATA SHEET

Patient Name: J.H. male Age: 26

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 5-11-88 Date Referred: 5-18-88

AROM: L Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 90	MCP 0 / 93	MCP 0 / 93
PIP 0 / 77	PIP 0 / 110	PIP 0 / 112
DIP 0 / 50	DIP 0 / 71	DIP 0 / 75
TAM 217	TAM 274	TAM 280

Comparison: 98 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	61	/	66
Trial 2	67	/	70
Trial 3	66	/	69
Average:	64.7	/	68.3

Comparison: 95 %

Comments: Continued to work during rehab. RTW after one week.

EXTENSOR TENDON DATA SHEET

Patient Name: M.H. male Age: 31

Surgeon: Dr. T. Involved Hand: Right / Left

DOI: 6-20-90 Date Referred: 6-25-90

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 87	MCP 0 / 90	MCP 0 / 89
PIP 0 / 83	PIP 0 /104	PIP 0 /106
DIP 0 / 44	DIP 0 / 68	DIP 0 / 67
TAM 214	TAM 262	TAM 262

Comparison: 100 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	84	/	105
Trial 2	95	/	90
Trial 3	95	/	98
Average:	91.3	/	98

Comparison: 93 %

Comments: Pt. returned to full duty without report of pain or difficulty. Reports no AM stiffness. Missed one week of work.

EXTENSOR TENDON DATA SHEET

Patient Name: A.K. male Age: 42

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 9-18-87 Date Referred: 9-24-87

AROM: R Little finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP NT /	MCP 0 / 94	MCP 0 / 95
PIP /	PIP -30 / 110	PIP -35/ 110
DIP /	DIP +23 / 44	DIP +10/ 50
TAM	TAM 241	TAM 230

Comparison: 105 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	82	/	80
Trial 2	83	/	83
Trial 3	86	/	85
Average:	83.7	/	82.7
Comparison:	101 %		

Comments: Unique anatomy involving pre-existing PIP joint contractures of little, ring and middle fingers. Missed one week of work.

EXTENSOR TENDON DATA SHEET

Patient Name: G.P. male Age: 26

Surgeon: Dr.L. Involved Hand: Right / Left

DOI: 4-28-89 Date Referred: 5-5-89

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 71	MCP 0 / 79	MCP 0 / 81
PIP 0 / 93	PIP 0 /110	PIP 0 /112
DIP 0 / 54	DIP 0 / 62	DIP 0 / 65
TAM 218	TAM 251	TAM 258

Comparison: 97 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	110	/	96
Trial 2	104	/	99
Trial 3	110	/	87
Average:	108	/	94

Comparison: 115 %

Comments: Returned to regular duty status at seven weeks post-op without difficulty or complaints.

EXTENSOR TENDON DATA SHEET

Patient Name: C.P. male Age: 26

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 9-15-89 Date Referred: 9-19-89

AROM: L Index finger

4 weeks p/o	6½ weeks p/o	Contralat. Finger
MCP 0 / 90	MCP 0 / 83	MCP 0 / 83
PIP -10/ 78	PIP -4 /112	PIP 0 /100
DIP 0 / 37	DIP 0 / 70	DIP 0 / 72
TAM 195	TAM 261	TAM 255

Comparison: 102 %

GRIP STRENGTH: 6½ weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	77	/	72
Trial 2	77	/	80
Trial 3	86	/	79
Average:	80	/	77

Comparison: 104 %

Comments: Pt. was discharged from therapy 6½ weeks post-op. Lost one day of work.

EXTENSOR TENDON DATA SHEET

Patient Name: T.S. female Age: 29

Surgeon: Dr.T. Involved Hand: Right / Left

DOI: 5-5-90 Date Referred: 5-11-90

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 85	MCP 0 / 87	MCP 0 / 85
PIP -5 / 84	PIP 0 /106	PIP 0 /108
DIP 0 / 30	DIP 0 / 49	DIP 0 / 58
TAM 194	TAM 242	TAM 251

Comparison: 96 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	71	/	55
Trial 2	69	/	67
Trial 3	71	/	63
Average:	70.3	/	61.7
Comparison:	114 %		

Comments: Complains of stiffness in AM but loosens up during warm shower. Lost eight weeks of work - employer requiring 100%.

EXTENSOR TENDON DATA SHEET

Patient Name: F.W. female Age: 46

Surgeon: Dr.D. Involved Hand: Right / Left

DOI: 7-1-90 Date Referred: 7-3-90

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP -12/ 63	MCP -4 / 75	MCP 0 / 67
PIP 0 / 83	PIP 0 / 95	PIP 0 /100
DIP 0 / 93	DIP 0 / 62	DIP 0 / 60
TAM 173	TAM 228	TAM 227

Comparison: 100 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	44	/	47
Trial 2	39	/	40
Trial 3	39	/	40
Average:	41	/	42

Comparison: 98 %

Comments: Swelling over MCP joint accounted for extension lag. Missed one day of work.

EXTENSOR TENDON DATA SHEET

Patient Name: C.A. female Age: 36

Surgeon: Dr. B. Involved Hand: Right / Left

DOI: 10-29-87 Date Referred: 11-3-87

AROM: R long finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 80	MCP 0 / 90	MCP 0 / 87
PIP 0 / 101	PIP 0 / 102	PIP 0 / 101
DIP 0 / 60	DIP 0 / 71	DIP 0 / 73
TAM 241	TAM 263	TAM 261

Comparison: 101 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	60	/	62
Trial 2	58	/	62
Trial 3	61	/	59
Average:	60	/	61

Comparison: 98 %

Comments: Returned to work 6½ weeks post-op as machinist.

APPENDIX G

Average Ranges of Joint Motion

Average Ranges of Joint Motion

The Committee on Joint Motion for the American Academy of Orthopaedic Surgeons developed estimates for average ranges of joint motion (American Academy of Orthopaedic Surgeons, 1965). Estimates for the fingers are as follows:

FINGERS:

	FLEXION	EXTENSION
MCP Joint	90 degrees	45 degrees
PIP Joint	100 degrees	0 degrees
DIP Joint	90 degrees	0 degrees

APPENDIX H

Grip Strength Norms

Adult Grip Strength

Average Performance of All Subjects on Grip Strength (Mathiowetz,1985)

		MEN		WOMEN	
Age	Hand	Mean	SD	Mean	SD
20-24	R	121.0	20.6	70.4	14.5
	L	104.5	21.8	61.0	13.1
25-29	R	120.8	23.0	74.5	13.9
	L	110.5	16.2	63.5	12.2
30-34	R	121.8	22.4	78.7	19.2
	L	110.4	21.7	68.0	17.7
35-39	R	119.7	24.0	74.1	10.8
	L	112.9	21.7	66.3	11.7
40-44	R	116.8	20.7	70.4	13.5
	L	112.8	18.7	62.3	13.8
45-49	R	109.9	23.0	62.2	15.1
	L	100.8	22.8	56.0	12.7
50-54	R	113.6	18.1	65.8	11.6
	L	101.9	17.0	57.3	10.7
55-59	R	101.1	26.7	57.3	12.5
	L	83.2	23.4	47.3	11.9
60-64	R	89.7	20.4	55.1	10.1
	L	76.8	20.3	45.7	10.1
65-69	R	91.1	20.6	49.6	9.7
	L	76.8	19.8	41.0	8.2
70-74	R	75.3	21.5	49.6	11.7
	L	64.8	18.1	41.5	10.2
75 +	R	65.7	21.0	42.6	11.0
	L	55.0	17.0	37.6	8.9

This is the normative data taken from the study performed by Mathiowetz, Kashman, Volland, Weber, Dowe and Rogers (1985).

APPENDIX I

Extensor Tendon Data Sheet for Patients Treated with Initial Immobilization

EXTENSOR TENDON DATA SHEET

Patient Name: W.S. male Age: 33

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 2-9-87 Date Referred: 3-4-87 (3½ wk.)

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 56	MCP 0 / 92	MCP 0 / 92
PIP -14 / 45	PIP 0 / 100	PIP 0 / 105
DIP -2 / 21	DIP 0 / 55	DIP 0 / 71
TAM 106	TAM 247	TAM 268

Comparison: 92 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	135	/	162
Trial 2	138	/	162
Trial 3	140	/	167
Average:	137.7	/	163.7

Comparison: 84 %

Comments: Pt. discharged nine weeks post-op with home program for ROM and strength.

EXTENSOR TENDON DATA SHEET

Patient Name: J.T. male Age: 27

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 12-30-86 Date Referred: 1-20-87 (3 wks.)

AROM: R Index finger

4 weeks p/o	8 weeks p/o	Contralat. Finger
MCP -6/ 90	MCP 0 / 90	MCP 0 / 90
PIP -2/ 75	PIP 0 / 87	PIP 0 /110
DIP -5/ 22	DIP -5 / 55	DIP 0 / 76
TAM 174	TAM 227	TAM 276

Comparison: 82 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	10	/	101
Trial 2	12	/	100
Trial 3	10	/	100
Average:	10.7	/	100.3

Comparison: 11 %

Comments: At eight weeks Pt c/o continued pain avoids flexion and grasping. D/C'd after fourteen weeks still unable to grip. 2° surgery 8/87 & 9/88.

EXTENSOR TENDON DATA SHEET

Patient Name: B.C. male Age: 58

Surgeon: Dr.B. Involved Hand: Right / Left

DOI: 9-11-86 Date Referred: 10-22-86

AROM: L Middlefinger

6 weeks p/o	8 weeks p/o	Contralat. Finger
MCP 0 / 88	MCP 0 / 90	MCP 0 / 90
PIP 0 / 71	PIP 0 / 90	PIP 0 /110
DIP -13/ 40	DIP -14/ 53	DIP 0 / 69
TAM 186	TAM 219	TAM 269

Comparison: 81 %

GRIP STRENGTH: 8 weeks p/o

Handle Position #2

	Involved	/	Uninvolved
Trial 1	55	/	105
Trial 2	55	/	103
Trial 3	58	/	105
Average:	56	/	104.3

Comparison: 54 %

Comments: Pt. had continued swelling in hand. Had been immobilized for six weeks following surgery. D/C'd after twelve weeks p/o. Continued pain with flexion.