Rehabilitation Following Extensor Tendon Injuries
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I. Historical Perspective
   A. Early motion inspired by complications associated with immobilization: insufficient tendon excursion, extensor lag, associated joint stiffness.
   B. The shift from immobilization to early passive motion began in the mid 1980's for zones V,VI,VII; for zone III in the 1990's; and immediate active tension and relative motion splinting more popular in the past few years.

II. Rationale for Immediate Active Tension (as for flexor system)
   A. The effects of immobilization
      1. loss of glycosaminoglycan concentration
      2. loss of water
      3. decreased fibronectin concentration
      4. decreased endotenon healing
      5. loss of gliding function
      6. imposed injury to uninvolved tissues by immobilization
   B. The effects of controlled stress; biochemical/biomechanical benefits
      1. improved tensile strength
      2. increased fibronectin concentration/ fibroblast chemotaxis
      3. increased repair site DNA
      4. improved synovial diffusion in synovial regions
      5. improved cellularity with both *motion* and *tension*
      6. maintain homeostasis in uninvolved tissues
   C. The effect of timing

III. Indications/Contraindications for Active Tension
   A. Not limited to any specific repair technique
   B. Appropriate for simple and especially complex injury if associated osseous injury will tolerate controlled motion and if the patient can understand treatment protocols
   C. Optimum time to start motion: 24-48 hours post-operative
   D. Caution if patients started late (>10 days)
   E. Patients need to be monitered in therapy 2/3 times per week for first 3 to 4 weeks

IV. General Considerations
   A. Variables of clinical decision making
      1. Level and complexity of injury (adjacent tissue injury)
      2. Biologic state of host/ personality and age of patient
      3. Repair technique/tensile strength of repair/tension on repair
      4. Drag which will determine resistance to tendon gliding
      5. Timing of referral to therapy: Early referral by day 3 preferred, and supported by basic science studies; referral at day 10 or greater will have associated problems of tendon to bone adherence which will elevate internal tension at the repair site with applied stress to the repair.
   B. Controlling inflammation
   C. The position of immobilization
   D. Duration of exercise
   E. Physiologic excursion
   F. Application of force
      1. Internal tendon tension transmitted to the repair site with specific joint angles and external loads (splinting configurations/exercise positions)
   G. Resistance to tendon gliding

V. Guidelines for Zones I and II

A. The mallet or baseball finger; lesion to the terminal extensor tendon; *early motion not appropriate for DIP, zone I extensor injury; Untreated the mallet finger becomes chronic and leads to a swan neck deformity and DIP OA.*

1. Splint position: DIP joint splinted at absolute 0 degrees extension to 5-10 degrees hyperextension (no more!) with volar thermoplastic splint taped directly over the DIP joint. Skin must be protected with moleskin or cotton interface. Apply dorsal interlocking splint for PIP joint at 40 degrees flexion in combination with distal joint splinting first 3 weeks post injury and at night 6 weeks to relax lateral bands (Bunnell 1944; Saito 2016). Custom splints produce superior results.

Prefabricated orthoses were found to increase the risk of developing skin complications as compared with custom-made orthoses, but there were no differences in treatment success, failure, or extensor lag (Witherow EJ et al 2015). Salazar et al (2016) recommend a dorsal glued splint except for stage IV which they treat with extra-articular pinning.

2. Timing: continuous immobilization 6-8 weeks dependent on ability of extensor tendon to hold DIP joint; followed by graded increase in flexion and intermittant splinting another 2 to 4 weeks
3. Exercise: Maintain PIP motion, gentle hyper-extension of DIP when seen in therapy for rechecks if no associated fx; at 6 weeks add 20 degrees flexion per week.
4. Frequency of therapy determined by condition of skin and patients ability to follow instruction regarding splinting.

VI. Guidelines for Treatment Zones III, IV

A. Zones III and IV: Open or closed injury to the extensor tendon over the PIP joint or proximal phalanx may result in a boutonniere deformity/volar migration lateral bands

1. Splint position
   a. traditional management: Uninterrupted splinting of the PIP joint at absolute 0 degrees extension for 4 to 6 weeks with digital cylinder casting or volar thermoplastic splinting
   b. SAM protocol (see Evans J Hand Surg 19A:991-997, 1994) Volar digital static extension splint for PIP and DIP joints holding both at 0 degrees of extension between exercises
2. Timing: SAM protocol for immediate active *short arc motion* preferably 24 hours post-operative (for open injury and repaired tendon)
3. Exercise: template splint 1 allows 30 degrees PIP flexion and extension (DIP is allowed to flex simultaneously to 25 degrees). Template splint 2 positions the PIP at O degrees and is cut away at the DIP level. Full DIP flexion is allowed if the lateral bands were not repaired, but only 25 degrees flexion is allowed if the lateral bands were repaired. *If no lag* develops 40 degrees PIP flexion is allowed by week 3, and 60 to 70 by the end of week 4; 90 by week 6. Exercise position is wrist 30 degrees flexion, MP at 0 degrees to slight flexion and IP joints as described within the template splints. (see Evans RB, Thompson DE. J Hand Ther 6:4. 266-284, 1993)
4. Clinical results: 64 digits in 55 patients with open and repaired zone III extensor tendon injuries compared as two groups; 76%/77% complex in groups I (3-6 weeks immobilization) and II (immediate active short arc motion) . Early motion group (SAM) experienced less extensor lag (-13 vs.-3), improved flexion (PIP and DIP, shorter treatment time (76 vs. 51days to discharge), and no boutonniere deformity.

Relative motion splinting for both operated and conservative treatment of the boutonniere deformity has recently been suggested (Merritt 2014);

VII. Guidelines for Treatment Zones V-VII

A. Zones V and VI: EDC has 11 to 16 mm of excursion at these levels requiring protection of both wrist and digital joints within the immobilizing splints.

1. Splint Position:

a. Treatment by *immobilization*. Not recommended unless patient is very young or non-compliant.
wrist extension 30-40 degrees; MP joints 0 to 20 degrees; PIP joints 0 degrees. Consider the junturae tendinum, and independent tendons to index and small when planning splint design

b. *SAM protocol*: Dynamic extension splint allowing 30-35 degrees at MP level for index and long, 40 to 45 degrees for ring and small; volar interlocking splint to prevent greater degrees of flexion; or stop beads. Add digital volar static extension splints within the slings if the digits do not rest at 0 degrees extension at all joints.

2. Timing: 24 hours post-op preferred

3. Exercise: active flexion, passive extension performed in the confines of splint by patient, 20 times per waking hour (they will move more and will also move actively inadvertantly). Under therapist supervision, splint should be removed to insure that MP joints all have at least 40 to 45 degrees motion (hold wrist and IP joints at O during this passive motion). Wrist can be moved from full extension to neutral with all digital joints held in full extension; with wrist and MP joints held in full extension the PIP joints can be moved from 0 to at least 60 degrees flexion. An active component can be added with tendon repairs that have at least 1200 grams of tensile strength. The therapist positions the hand with wrist at 20 degrees flexion, MP joints at 0 and asks the patient to gently maintain the position. This insures some active tension and proximal migration of the repair site.

4. Clinical results

Sagittal Band Injury

Manage with MP extension splinting at 0 4 weeks (Kleinhenz BP et al 2015) or relative motion splinting (Merritt 2014) if injury is identified within 3 weeks of injury (Fernandez-Vasquez et al 2016))

The juncturae tendinum appear to have a role in stabilising the extensor communis tendons at the MCP joints and preventing radial subluxation after ulnar sagittal band rupture. (Farrar NG Kundra A, 2012)

B. Dynamic splinting for Zone VII,VIII

1. Tendons are synovial at this level and encased in six fibroosseous canals...problems exist similar to zone II flexor. Scarring proximal to the retinaculum creates a tenodesis effect. Wrist motion (therapist supervised) is important at this level (full extension to neutral) to effect true excursion of the EDC; place and hold as described above is recommended for true proximal tendon migration.

2. Limited tendon excursion associated with repairs under or in close proximity to the extensor retinaculum/ synovial pouches at the wrist level. Dynamic traction for the digits with the wrist immobilized, or controlled motion during formal therapy sessions are often insufficient to prevent inter-tendinous adhesion.

3. Functional limitations with injury proximal to zone VIII may limit composite wrist and digital flexion as the tendon will not glide distal; injury proximal zone VI will limit composite wrist and finger extension as the tendons will not glide proximal under the retinaculum; both problems can occur at level VII.

4. “Double Reverse Kleinert Technique” (Chinchalkar SJ, Chinchalkar S, J Hand Ther. 2004 Oct-Dec;17(4):424-6.

allows controlled dynamic flexion of wrist with simultaneous finger extension to promote some physiologic excursion at synovial/retinacular level.

C. ICAM Program (Howell et al. J Hand Ther 18:2, 2005) or relative motion splinting (Relative motion splinting: (Hirth MJ, Howell JW, O'Brien L 2016)

1. Immediate controlled active motion for zone 4-7 extensor tendon repairs
2. Allows greater arcs of motion for adjacent digits
3. The splint is designed to relieve tension on the tenorrhaphy by positioning the involved digit in slight metacarpophalangeal joint hyperextension relative to the uninvolved digits with a simple yoke splint designed to control the metacarpophalangeal joints and a second splint to control wrist position.

D. Evidence Zones V-VIII : Support for dynamic over static spinting: a systematic review. (Sameem et al JHT 2011)

VIII. Guidelines for Treatment of the Extensor Pollicis Longus

A. Zones TI and TII: treat as zones I and II in the digit.

Injuries in T-I and T-II are treated similarly to injuries of zones I and II of the finger. Reports in the literature on the mallet thumb indicate that the injury is rare and that opinions differ concerning surgical repair versus conservative treatment with splinting. Zone T-I injuries require that the IP joint be splinted for 8 weeks continuously at 0° or slight hyperextension with conservative management, and 5 to 6 weeks with operative repair. Both approaches require an additional 2 to 4 weeks of splint immobilization between exercise sessions. Increments in flexion as mobilization is initiated should be no more than 20° per week and delayed if extensor lag develops. IP joint extension splinting should be continued between exercise periods and at night for an additional 2 to 3 weeks. Pinching and gripping activity with mild resistance can be initiated between the sixth and eighth weeks, depending on the duration of immobilization. Zone T-II injuries are immobilized with a hand-based static splint that immobilizes the MCP and IP joints at 0° and radially extends the thumb. Active motion can be initiated in the short arc (25-30°) by the third week, progressing slowly with more joint motion for the next 3 weeks. The problems of tendon-to-bone adherence will be similar to the digit over the proximal phalanx. Splint protection between exercise sessions is needed for a total of 6 weeks.

B. Zones III and IV:

Injuries in zones T-III and T-IV should be splinted with the thumb MCP joint at 0° and slight abduction and the wrist in 30° of extension. Care must be taken that the MCP joint does not rest in hyperextension or that the immobilizing splint does not migrate distally, hyperextending this joint. Regaining flexion at the MCP joint level is difficult in either case and may extend required rehabilitation. If the MCP joint is tight in hyperextension, dynamic splinting for the MCP joint with a gentle traction and joint mobilization techniques that use simultaneous axial distraction and flexion will help elongate the periarticular structures so that flexion can be regained.

C. Zone TV is synovial and should be considered a complex injury.

Zone T-V injuries create difficult rehabilitation problems. Dense adhesions frequently limit excursion of the EPL at the retinacular level. Improper immobilization in which the MCP joint is hyperextended or in which insufficient web space is maintained will create extension contracture of the MCP joint, first-web contracture, and problems in regaining ligamentous extensibility and tendon glide. Dynamic flexion splinting of the MCP joint with the wrist and first metacarpal extended is appropriate treatment for MCP joint extension contracture between weeks 3 and 4 if the rubber band traction is less than 250 g and the anastomosis is protected from excessive stress by proper positioning of the proximal joints. Combinations of abduction and flexion splinting and exercise are appropriate between weeks 4 and 5 for excursion problems at this level.

Early motion.

*Excursions for the EPL vary in the literature from 25 to 60 mm and are subject to many variables.

*Evans and Burkhalter measured the EPL intraoperatively and determined that, with the wrist in a neutral position and the thumb MCP joint extended to 0°, 60° of IP joint motion effected 5 mm of tendon excursion at the level of Lister's tubercle. Extending the wrist beyond approximately 30° most likely would change the excursion with IP motion.

*Tendon gliding for the EPL has been studied in zone IV during passive motion in four different wrist positions in 25 healthy female volunteers using high-resolution ultrasonography. It was determined that the mean gliding distance of the EPL tendon was 1.79, 2.45, 1.09, and 1.36 mm with the wrist positioned in neutral, 30° of extension, 30° of flexion, and 20° of ulnar deviation, respectively. Wrist extension was found to induce the greatest magnitude EPL tendon gliding. (Chen et al 2009)

*The early passive motion technique requires dynamic splinting that immobilizes the wrist in extension, the MCP joint at 0°, and the IP joint at 0° in dynamic traction. The volar component of the splint is cut away at the IP joint, allowing the prescribed 60° of IP motion to take place I have altered my original approach to these injuries by adding other motions while the patient is in my hands. Passive motion by the patient is supplemented in therapy with controlled passive motion to the MCP joint of approximately 30° while the wrist is held in maximum extension and the IP joint is held at 0°; by abduction and adduction motions for the CMC joint in a 50% to 60% range; and by wrist tenodesis exercise in which the wrist is moved to a 0° position while the thumb kinetic chain is held in maximum extension, the thumb is relaxed, and the wrist is moved to full extension. To ensure that the tendon repair site is truly migrating proximally, I also add a component of "active hold." After the passive exercise, which will help minimize drag by reducing the resistance of edema and joint stiffness, the wrist is placed in 20° of flexion while the CMC, MCP, and IP joints are held in extension and the patient is asked to gently maintain this position. The wrist position of minimal flexion reduces the elastic drag of the antagonistic flexor pollicis longus (FPL) and thus reduces the internal force applied to the repair with the active hold portion of the exercise. The patient may come out of the protective splint during exercise and for showering during the third to fourth weeks, but splint protection should be maintained otherwise. Each joint should be moved actively into graded increments of flexion while all other joints in the thumb and the wrist are held in extension during the third and fourth weeks. By the fifth week, composite thumb flexion and opposition exercises may be initiated. Modalities and schedules for adding resistance for the tendon at this level are the same as for the digit. Continuous repetitive motions or overuse of therapy putty may inflame the tendons in the first dorsal compartment, creating a de Quervain's tendonitis in the overambitious patient trying to regain flexion

Complications associated with distal radius fx/ volar plating/ numerous papers in the literaature

Flexor pollicis longus rupture (Monaco NA **et al 2106;** (Fan J et al 2016)
EPL tendon injury was found to be a complication unique to the dorsal entry approach for ESIN of the radius. (Murphey et al 2016)

IX. Summary/ Conclusions

Results following repair of the extensor system have been improved with regards to final ROM, time from injury to recovery, expense, and functional outcomes with the treatment advances associated with early motion. Unlike early motion programs for flexor tendons the risk of rupture or associated complications in the experience of this author is low if guidelines for exercise position, force application, and splint geometry are followed. The results cited by this author and those reported by others demonstrate that early controlled motion for extensor tendon injuries in zones III-VII, and TIV,IV is safe and effective if force application and splint positions are precise. Early referral to therapy, meticulous care in the control of edema, patient education, precise positions of post-operative splinting, and controlled motion programs combining both passive and active tension will greatly improve the results of both complex and simple extensor

tendon injury not only in terms of function achieved, but in terms of rehabilitation time, expense, and lost time from work. Relative motion splinting first described by Robinson, Rosenblum and Merritt at the ASHT scientific meeting in 1986 has gained popularity and support with excellent results over the past few years/ these concepts to be reviewed by Juliane Howell, who has also written extensively on the subject, in the panel today.

EVIDENCE: No conclusive evidence found regarding long term (weeks) effectiveness of the different rehabilitation protocols (Talsma 2008); Level 3 evidence found supporting dynamic over static splinting post op (Sameem et al 2011)

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