Extensor Tendon Injuries: Acute Management and Secondary Reconstruction

Learning Objectives: After reviewing the article, the participant should be able to: (1) Describe the anatomy of the extensor tendons at the level of the forearm, wrist, hand, and fingers. (2) Recognize variations in the anatomy. (3) Master the hand examination and define the relevant findings in acute injuries of the extensor tendon(s). (4) Delineate the techniques for extensor repair in both acute and secondary (delayed) management.

Summary: Extension of the fingers is an intricate process that reflects the combined action of two independent systems. The interossei and lumbricals constitute the intrinsic musculature of the hand. These muscles innervated by the median and ulnar nerves extend the proximal interphalangeal and distal interphalangeal joints and flex the metacarpophalangeal joints. The extrinsic extensors are a group of muscles innervated by the radial nerve, originating proximal to the forearm. The extrinsic digital extensor muscles include the extensor digitorum communis, extensor indicis proprius, and extensor digiti quinti. The digital extensors function primarily to extend the metacarpophalangeal joints, but also extend the proximal interphalangeal and distal interphalangeal joints. Normal extensor physiology reflects a delicate balance between these two unique extensor systems. In the injured hand, a functioning intrinsic system may potentially compensate for an extrinsic deficit. An understanding of the relevant anatomy and an appreciation for the complex interplay involved in extensor physiology is necessary to recognize and manage these injuries. (Plast. Reconstr. Surg. 121: 109e, 2008.)

ANATOMY

Forearm

There are two compartments of muscles, comprising a superficial layer and a deep layer. The muscles of wrist extension, the extensor carpi radialis brevis, extensor carpi radialis longus, and the extensor carpi ulnaris, originate on the lateral condylar ridge and lateral epicondyle of the distal humerus. These muscles along with the extensor digiti quinti make up the superficial layer.

The deeper layer of muscles includes the finger and thumb extensors. These muscles have a broad origin, including the lateral epicondyle, the proximal radius, the proximal ulna, and the interosseous membrane.1,2

Wrist

The tendons enter the hand through six compartments formed by the extensor retinaculum. The first compartment contains the extensor pollicis brevis and the abductor pollicis longus; the second, the extensor carpi radialis longus and extensor carpi radialis brevis; the third, the extensor pollicis longus; the fourth, the four tendons of the extensor digitorum communis plus the extensor indicis proprius; the fifth, the extensor digiti quinti; and the sixth, the extensor carpi ulnaris (Fig. 1). The extensor indicis proprius and extensor digiti quinti typically lie deep and ulnar to the extensor digitorum communis at the metacarpophalangeal joints.

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Hand

Several anatomical studies have analyzed the extensor anatomy in zone VI, the dorsum of the hand. This area represents the region of greatest variability in extensor anatomy. The juncturae tendinum or intertendinous connections are fibrous connections between the extensor tendons of the fingers proximal to the metacarpophalangeal joints. There are three juncturae, which exhibit a high degree of variability. Junctura A connects the extensor tendons of the index and long fingers. Junctura B connects the long and ring finger extensor tendons. Finally, junctura C connects the ring and small finger tendons (Fig. 2). Von Schroeder et al. classified the patterns of juncturae tendinum into three types: type 1, filamentous band; type 2, fibrous band; and type 3, tendinous band.

In a recent study, Hirai et al. analyzed 548 cadaveric upper extremities and found the most common pattern of intertendinous connections to be type 1 in the second intermetacarpal space and type 3 in the third and fourth intermetacarpal spaces. The functions associated with the juncturae include spacing of the extensor digitorum communis tendons, force redistribution, coordination of extension, and stabilization of the metacarpophalangeal joints. A lacerated extensor tendon may be overlooked if digital extension is partially maintained through intact juncturae tendinum. This often occurs in zone VI, where lacerations proximal to the juncturae allow for retained function through an adjacent extensor digitorum communis tendon (Fig. 3).

Fingers

The extrinsic extensors are the sole extensors of the metacarpophalangeal joint but can also produce extension at the interphalangeal joints, provided that hyperextension is controlled (Fig. 4).
The extensor digitorum communis tendons pass over the metacarpophalangeal joint and are held in position by the sagittal bands. The sagittal bands wraps around the metacarpophalangeal joint to attach to the volar plate by an encircling series of fibers by means of the transverse metacarpal ligament. It is this attachment that allows the extensor digitorum communis to extend the metacarpophalangeal joint and thereby extending the proximal phalanx. These sagittal bands maintain the extensor tendon in the midline over the metacarpophalangeal joint and, along with the intrinsic muscles, prevent hyperextension (Fig. 5).

Distal to the metacarpophalangeal joint, the extensor digitorum communis trifurcates. The central portion continues distally and attaches to the base of the middle phalanx (central slip). The central slip is joined by a medial band of oblique fibers from the lumbricals and interossei. Together, they extend the proximal interphalangeal joint. The lateral slips of the extensor tendon pass on either side of the proximal interphalangeal joint and join with the lateral bands of the intrinsic muscles to form the conjoined lateral bands. They reunite distally as the terminal tendon and insert into the distal phalanx (Fig. 6).

**Intrinsics**

The interossei and lumbricals constitute the intrinsic musculature of the hand. The three palmar interossei arise with a single head each from the second, fourth, and fifth metacarpals. The muscles are bipennate, measuring between 45 and 55 mm in length. The volar interossei have no bony attachments; rather, they insert onto the lateral band and dorsal aponeurosis of the finger from which they arise. They adduct and flex the proximal phalanges and extend the interphalangeal joints. The dorsal interossei, apart from the third, have two muscle bellies. The superficial or dorsal belly inserts onto the base of the proximal phalanx. This belly functions as an abductor and weak flexor of the proximal phalanx. There is no direct effect on interphalangeal extension. The deep or volar belly continues as the lateral tendon and forms the lateral band of the dorsal aponeurosis. It flexes and abducts the proximal phalanges, and extends the interphalangeal joints. Both palmar and dorsal interossei pass dorsal to the deep transverse metacarpal ligament, which separates them from the lumbrical tendons.

The lumbricals are unique muscles in that they arise from a flexor tendon and insert onto an extensor tendon. They arise from the flexor digitorum profundus and insert onto the radial band of each finger. The lumbricals function as the prime intrinsic interphalangeal extensors. The exact action of the lumbrical is dependent on simultaneous contraction or relaxation of its parent flexor digitorum profundus. Flexor digitorum profundus contraction will flex the interphalangeal joints, provided that the lumbrical relaxes. Conversely, lumbrical contraction will produce interphalangeal joint extension if the profundus tendon is relaxed. The interossei contribute to interphalangeal extension only when the metacarpophalangeal joints are flexed simultaneously. The interossei, with their large cross-sectional area, are the predominant metacarpophalangeal joint flexors.
The abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus tendons insert on the bases of the first metacarpal, proximal, and distal phalanges, respectively (Fig. 7). The extensor pollicis longus tendon acts with relative independence across all three joints through the attachments of the dorsal apparatus. The tendon of the abductor pollicis brevis also forms a broad expansion that fuses with the extensor pollicis longus tendon. To this effect, the extensor pollicis longus is maintained in a central fashion by contraction of the opposing muscle groups. In the event the extensor pollicis longus is divided distal to the metacarpophalangeal joint, it will be maintained out to length by these attachments. The thumb has no lumbricals or interosseous muscles. The only intrinsic muscle function is derived from the adductor muscle and thenar muscles: the abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis.

**ANATOMICAL VARIATIONS**

Anatomical variations in the anatomy of the extensors are common.

**First Compartment**

Gonzalez et al. reported septation in the first compartment in 31 of 66 hands and multiple abductor pollicis longus slips in 38 hands. In the first dorsal compartment, septation occurs in 20 to 60 percent of specimens. The abductor pollicis longus may have multiple slips in 56 to 98 percent of dissections.

**Second Compartment**

Wood reported the presence of a third radial wrist extensor, the extensor carpi radialis intermedius, in 12 percent of cadaveric specimens.

**Third through Fifth Compartments**

Von Schroeder and Botte detailed these variations in a cadaveric study. Common variations in the extensors to the fingers reported by von Schroeder and Botte include a double extensor indicis proprius, double or triple extensor digitorum communis to the long finger, single or triple extensor digitorum communis to the ring finger, and single or double extensor digitorum communis to the small finger.

The extensor digitorum communis to the little finger may be absent in as many as 56 percent of cases. In the case of absence of the little finger extensor digitorum communis, a juncture from the ring finger will pass to the extensor hood at the metacarpophalangeal joint of the little finger. Gonzalez et al. noted that both the extensor digitorum communis tendon and a junctura were absent in 6 percent of cases. Transfer of the extensor digiti minimi in these cases could result in loss of extension of the little finger.

In a separate study, Gonzalez and colleagues identified variations in the extensor indicis proprius in 19 percent of specimens. They noted duplication of the extensor indicis proprius in 10 of 66 hands and duplicate slips of the extensor digitorum communis in two specimens.

**ACUTE INJURIES**

Kleinert and Verdan described a classification system for extensor tendon lacerations according to eight zones in the hand, wrist, and forearm.

**Mallet Finger (Zone I)**

Green describes the hallmark of the mallet finger as a loss of active extension at the distal interphalangeal joint. The mechanism of disruption involved in these injuries is most often a sudden, forced flexion of the distal interphalangeal joint in an extended digit. The injury itself can be either open or closed but is most often a closed injury. These injuries are classified into four types:

- **Type I:** Closed, with or without avulsion fracture.
- **Type II:** Laceration at or proximal to the dip joint with loss of tendon continuity.
- **Type III:** Deep abrasion with loss of skin, subcutaneous soft-tissue coverage and, in addition, tendon substance.
Type IV:
A. Transepiphyseal plate fracture in children.
B. Hyperflexion injury with fracture of the articular surface of 20 to 50 percent.
C. Hyperextension injury with fracture of the articular surface usually greater than 50 percent and with early or late palmar subluxation of the distal phalanx.
Management of these injuries is varied, ranging from simple immobilization to aggressive open reduction and internal fixation. Extension splinting of just the distal interphalangeal joint has become the standard of care for most mallet injuries (Fig. 8). Splinting is continuous for a period of 6 to 8 weeks. After this initial phase of continuous splinting, the patient should be slowly weaned from the splint. At the first sign of regression (extensor lag), the patient should be returned to continuous splinting. Most authors report a success rate of approximately 80 percent with this strategy.

Indications for operative treatment are controversial. The three most common indications cited include (1) open injuries (types II and III), (2) those individuals who are noncompliant or unable to tolerate a splint, and (3) in cases where there exists a large dorsal fragment with palmar subluxation of the distal phalanx (type IV). Several techniques have been described for treatment of the mallet finger, including mattress sutures, pull-out wires, running sutures or wires, and fixation with Kirschner wires (Fig. 9). Doyle describes Kirschner wire fixation of the distal interphalangeal joint for 6 weeks followed by nighttime splinting for 2 weeks.

Chronic Mallet Finger

Many patients accept the deformity associated with a mallet injury and never, in fact, seek medical attention. The appearance alone, however, is often enough for patients to seek treatment, even several months after the initial injury. Other common reasons patients may seek delayed treatment include pain in the joint, secondary deformities including a swan-neck deformity, and a hooked deformity in which the finger may get in the way. Splinting should still be considered the first line of treatment in those patients who present late. Several authors have provided evidence that immobilization, even in those patients presenting late, is always beneficial.16–18 The initial work was performed by Abouna and Brown, in which 17 of 25 patients with recurrent mallet deformities were treated with further immobilization. Their results demonstrated that further immobilization is always beneficial, and that the longer it can be maintained, the better the result.

Surgery has traditionally been the therapy of choice for patients who initially fail conservative management or for those individuals that present with recurrent, chronic mallet deformities. There are many surgical options that address the chronic mallet deformity. These include the following:

1. Immobilization with transarticular Kirschner wire fixation across the affected joint.
2. Excision of tendon-scar unit and fixation in hyperextension.
3. Fowler’s central slip release.

Salvage techniques include distal interphalangeal joint arthrodesis or amputation.

Middle Phalanx (Zone II)

Injuries are typically seen with sharp lacerations, saw injuries, and crush injuries. Doyle recommended a running core suture oversewn with a Silfverskiöld epitendinous stitch. Acute lacerations with extensor lag present on examination necessitate exploration and repair. Active extension with some weakness against resistance is treated with splinting for 3 to 4 weeks.

Proximal Interphalangeal Joint and Boutonnière Deformity (Zone I)

Abnormality

Abnormality begins with injury to the central slip. Initially, active extension is retained by means of the lateral bands. Over time, however, the head of the proximal phalanx herniates through the central slip defect, stretching or even tearing the triangular ligament. The result is volar migration of the lateral bands. This, in effect, transforms the lateral bands from proximal interphalangeal extensors into proximal interphalangeal flexors. In addition, the volar positioning of the lateral bands increases the tension on the bands, producing distal interphalangeal joint hyperextension. The initial deformity is often reducible; however, without treatment, it rapidly becomes a fixed flexion deformity contraction. Green provides three reasons for this contraction:

1. The transverse retinacular ligaments contract, holding the lateral bands in a fixed position volar to the proximal interphalangeal joint axis of rotation.
2. The oblique retinacular ligaments contract similarly, accentuating the distal interphalangeal joint hyperextension.
3. The volar plate and accessory collateral ligaments contract to create a fixed flexion deformity at the distal interphalangeal joint.

Figure 10 demonstrates operative management of a chronic type 2 boutonnière deformity.

Cause

Causes include the following:

1. Closed: includes crush injuries and volar dislocations. The mechanism entails forced flex-
ion of an actively extended proximal interphalangeal joint, thereby detaching the central slip and possibly avulsing the dorsal base of the mid phalanx.

2. Open: involves laceration of the central slip and may include open wounds with tendon necrosis and also burns.

3. Infected: subcutaneous and intraarticular infections with tissue necrosis or devitalized tendon can result in disruptions of the central slip.

4. Inflammatory: rheumatoid arthritis and other inflammatory disorders are commonly associated with this deformity.

**Treatment**

The treatment of acute injuries is designed to prevent the boutonnière deformity. If a laceration to the central slip is diagnosed at the time of injury, reapproximation of the central slip should be undertaken. Closed injuries should be treated with splinting alone.

**Proximal Phalanx (Zone IV)**

Partial lacerations encompassing greater than 50 percent and complete lacerations are repaired with a modified Kessler technique. Several studies have evaluated the various repair techniques in zone IV. Newport and colleagues demonstrated that the modified Kessler stitch would not shorten the tendon or limit flexion at the proximal interphalangeal and distal interphalangeal joints. The rehabilitation following repair is discussed below.
Dorsal Hand (Zone VI)

Injuries through or just distal to the juncturae tendinum may be difficult to diagnose because of the minimal extensor lag associated with these injuries. Injuries occurring proximal to the juncturae may result in retraction of the proximal stump, making repair technically more challenging.

The tendons in this zone are very superficial, covered only with thin paratenon and scant subcutaneous tissue. Degloving injuries are not uncommon and may require grafting, or local versus distant flap coverage.

Wrist (Zone VII)

Among proximal extensor tendon injuries, zone VII may have the worst prognosis. Injuries at this level usually produce mass healing of tendons to the underlying joint capsule and surrounding retinaculum. This may impair ultimate excursion after healing and frequently results in a tenodesis of the tendons at the wrist.

Injuries in the wrist often necessitate releasing the retinaculum for visualization and repair. At least a portion of the extensor retinaculum should be preserved to prevent bowstringing of the tendons. Early dynamic splinting may prevent or minimize postoperative adhesions.

Forearm (Zone VIII)

Injuries in the forearm may involve extensor muscle bellies, tendons, or the musculotendinous junctions. Actual muscle injuries should be repaired with liberal figure-of-8 stitches. Both injuries should warrant static mobilization for 5 to 6 weeks with the wrist extended to approximately 45 degrees (see below).

REHABILITATION

Conventional therapy has mandated immobilization for acute extensor tendon repairs. However, in recent years, the literature has supported early motion protocols after extensor tendon repairs. These protocols seek to promote tendon gliding, achieve a return in extensor strength, and protect the repair and prevent deformity and extensor lag.

Zone I

Nonoperative Management

The patient is placed in a volar static finger extension splint with the affected digit in approximately 10 degrees of hyperextension. In the presence of a pseudo–swan-neck deformity at the proximal interphalangeal joint, a tripoint splint can be incorporated into the distal interphalangeal joint. Immobilization is continued over a course of approximately 6 weeks.

Exercises begin with blocking exercises of the profundus, involving proximal interphalangeal joint active motion only.20 This regimen is continued for approximately the first 6 weeks.

At week 6, gentle active flexion of the distal interphalangeal joint is allowed to 30 degrees. Although full active extension is permitted, there remains no passive flexion. At weeks 7 and 8, active flexion is increased from 60 degrees to full. It is at week 10 and beyond that resistive exercises are begun. It is important to monitor for the presence of extensor lag throughout this period.

Postoperative Management

Postoperatively, the hand is placed in a hand-based, static, volar positioning splint. The splint should include the involved digit’s metacarpophalangeal and proximal interphalangeal joints. Immobilization is constant over the first 6 weeks, with exercises not being started until the sixth and seventh weeks.
Fig. 10. Surgical correction of a chronic type 2 boutonnière deformity.
Zone III

Stage I: Nonoperative Management

The affected digit is placed in a static finger extension splint (Fig. 11). During the initial 6 weeks, the proximal interphalangeal joint is immobilized completely. Exercises during this time focus on the distal interphalangeal joint. Active flexion and extension is repeated in the splint, with repetitions of 10 held for a count of 10 seconds.

At week 6, the splint is modified to allow for proximal interphalangeal joint active flexion to 30 degrees. Full active extension is permitted at this time; however, there remains no passive flexion. Gradually, the range of motion is increased to full over the course of the next 1 to 2 weeks. At week 10 and beyond, graded resistive exercises are initiated.

Stages II and III: Nonoperative Management

The following regimen may be initiated in the clinical scenario in which there is tightness associated with the oblique retinacular ligament or in the event that full passive proximal interphalangeal joint extension is not attainable. Serial casts in extension are applied and changed frequently to stretch contractures until the affected joint approximates neutral. The patient is asked to flex the distal interphalangeal joint every 2 hours to keep the oblique retinacular ligament stretched. Serial casting may be required of the metacarpophalangeal, distal interphalangeal, and proximal interphalangeal joints in advanced stage II, zone III injuries.

Postoperative Management

The affected extremity is placed in a hand-based volar positioning splint with the involved digit immobilized completely. During the initial 6 weeks, there is complete immobilization of the affected digit. The patient is simply monitored for splint fit and wear.

At week 6, active flexion is initiated to 30 degrees. At this time, full active extension is permitted. Again, no passive flexion is allowed at any time. Over the ensuing 2 to 3 weeks, active flexion is increased gradually to full range of motion. At week 10, graded resistive exercises are initiated.

Zones IV and VII

Postoperative Management

It is imperative that the surgical team effectively communicates and documents the exact type, location, and quality of the extensor repair. Likewise, it is critical to document the repair of any vessels or nerves that may affect the timing of rehabilitation.

Postoperatively, the patient is placed in a volar positioning splint. In the first 3 weeks, passive extension is allowed in the splint. In the event of a six-strand repair, gentle active range of motion can be initiated early (as soon as postoperative day 3).

At week 4, gentle active extension is monitored. Again, no passive flexion is allowed at any time. In the next 2 weeks, active flexion is initiated and graded resistive exercises are added to the regimen. During the entire time, the patient is evaluated continuously for the presence of extensor lag.

Zones V and VI

Early Mobilization

After repair of the extensor tendons, the patient is placed in a dynamic extension splint for early mobilization (Fig. 12). During the initial 4 weeks, the patient is allowed to perform active flexion to 30 degrees of metacarpophalangeal joint motion with passive extension by means of rubber band traction. The range of motion is increased gradually over the ensuing several weeks to full by week 5. After 5 weeks, the dynamic extension splint can be discontinued, provided there is no extensor lag or other complications present to interfere with motion. Once the splint is discontinued, the patient may begin active extension and flexion. Eventually, graded resistive exercises are begun to augment strength and mobility.

Fig. 11. Conservative treatment of a boutonnière deformity with proximal interphalangeal joint splinting.
Mowlavi et al. studied dynamic versus static splinting of simple zone V and zone VI extensor tendon repairs. In a prospective, randomized, controlled study, they demonstrated that dynamic splinting provided improved functional outcomes at 4, 6, and 8 weeks when compared with static splinting. However, there was no difference at 6 months and beyond. The authors therefore concluded that dynamic splinting should be offered to select patients who are motivated and desire earlier return to full functional capacity.21

**Thumb (Zones I through III)**

The affected extremity is initially placed in a thumb spica splint. During the first 3 weeks, the wrist is positioned to 30 degrees of extension. The thumb, carpometacarpal, metacarpophalangeal, and interphalangeal joints are all held in an extended manner (Fig. 13).

At week 3, gentle active extension of the interphalangeal, metacarpophalangeal, and carpometacarpal joints of the thumb is initiated. At weeks 4 to 5, there is continued gentle active extension with the addition of gentle active flexion of the same joints. At week 6 and beyond, graded resistive exercises are initiated.

**SUMMARY**

In the past several years, the extensor system has received considerable attention as we have come to understand the complexity involved in extensor tendon anatomy and appreciate the coordinated, complex interplay involved in upper extremity physiology. Until recently, extensor tendon injuries were often overlooked, with repairs being performed in emergency rooms, often by untrained professionals. The recent literature would support the notion that the extensor tendon system is challenging, with management necessitating a thorough understanding of both anatomy and the relevant physiology.

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**Table 1. CPT Codes Commonly Used in Extensor Tendon Surgery**

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<thead>
<tr>
<th>CPT Code</th>
<th>Descriptor</th>
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<tr>
<td>25270</td>
<td>Repair, tendon or muscle, extensor, forearm and/or wrist; primary, single, each tendon or muscle</td>
</tr>
<tr>
<td>25272</td>
<td>Repair, tendon or muscle, extensor, forearm and/or wrist; secondary, single, each tendon or muscle</td>
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<tr>
<td>25274</td>
<td>Repair, tendon or muscle, extensor, forearm and/or wrist; secondary, with free graft (includes obtaining graft), each tendon or muscle</td>
</tr>
<tr>
<td>26410</td>
<td>Repair, extensor tendon, hand, primary or secondary; without free graft, each tendon</td>
</tr>
<tr>
<td>26412</td>
<td>Repair, extensor tendon, hand, primary or secondary; with free graft (includes obtaining graft), each tendon</td>
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<tr>
<td>26418</td>
<td>Repair, extensor tendon, finger, primary or secondary; without free graft, each tendon</td>
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<tr>
<td>26420</td>
<td>Repair, extensor tendon, finger, primary or secondary; with free graft (includes obtaining graft), each tendon</td>
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<tr>
<td>26426</td>
<td>Repair of boutonnière; using local tissue, including lateral bands, each finger</td>
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<tr>
<td>26428</td>
<td>Repair of boutonnière; with free graft (includes obtaining graft), each finger</td>
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<tr>
<td>26433</td>
<td>Repair of extensor tendon, distal insertion, primary or secondary; without graft</td>
</tr>
<tr>
<td>26434</td>
<td>Repair of extensor tendon, distal insertion, primary or secondary; with free graft (includes obtaining graft)</td>
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