Chapter 268: Injuries to the Hand and Digits

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ANATOMY

The hand consists of 27 bones: 14 phalangeal bones, 5 metacarpal bones, and 8 carpal bones arranged in five rays of metacarpals and phalanges having its base at the carpometacarpal (CMC) articulation (Figure 268-1).

**FIGURE 268-1.**

A. Bones of the hand and wrist. B. Carpal tunnel.
The carpal bones are made up of two rows, each with four bones. The bones are concave volarly and are bridged by the flexor retinaculum. This forms the carpal tunnel through which the median nerve and the nine long flexor tendons of the fingers pass (flexor pollicis longus [FPL]; flexor digitorum profundus [FDP] from the index, middle, ring, and small fingers; and flexor digitorum superficialis [FDS] from the index, middle, ring and small fingers) (Figure 268-2).

FIGURE 268-2.
Joints, ligaments, and tendons of the digits.
The index and middle finger CMC articulations have relatively little mobility, whereas the thumb, ring, and small finger CMC articulations have greater mobility at the CMC joint, which allows grasping and adaptive movements of the hand. More metacarpal deformity can be accepted in the great mobility CMC joints.

Multiple soft tissue structures support the bones and joints of the hand: capsules and ligaments provide stability, whereas muscles/tendons of the hand and forearm generate mobility (Figures 268-2, 268-3, and 268-4). The collateral ligaments of the metacarpophalangeal (MCP) joints are tightest in flexion in the index through small fingers (to allow stability in grasp), while the collateral ligaments of the MCP thumb are tight in flexion and extension (which also provide stability for the thumb in all positions) (Figure 268-3). The collateral ligaments of the interphalangeal (IP) joints are also tight throughout the entire range of motion.

**INTRINSIC HAND MUSCLES**

The intrinsic muscles of the hand are those that have both their origins and insertions within the hand. They consist of the thenar and hypothenar muscles, the adductor pollicis, the interossei, and the lumbricals (Figures 268-3, 268-4, and 268-5).

**FIGURE 268-3.**
A. Palmar (volar) view of the hand showing the relationship of the some of the intrinsic muscles, and flexor tendons and sheaths. B. Cross-sectional view of digit at the middle phalanx. C. Lumbricals.
**A.** Dorsal view of the hand showing the extensor tendons and retinaculum, and intrinsic musculature. **B.** Cross-sectional view with the six extensor compartments.

**FIGURE 268-5.** Origins, insertions, and actions of the palmar and dorsal interossei.


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The thenar muscles (from superficial to deep: abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis) originate in the flexor retinaculum and carpal bones and insert on the radial base of the thumb proximal phalanx and the radial aspect of the first metacarpal. The motor branch of the median nerve innervates all three muscles except for the deep head of the flexor pollicis brevis, which is innervated by the ulnar nerve. The adductor pollicis is innervated by the ulnar nerve and originates from the capitate and second and third metacarpals and inserts on the ulnar base of the thumb proximal phalanx.

The hypothenar muscles include, from superficial to deep, the abductor digiti minimi, the flexor digiti minimi, and the opponens digiti minimi. These muscles, innervated by the ulnar nerve, originate in the flexor retinaculum and carpal bones and insert at the ulnar base of the small finger proximal phalanx and the ulnar aspect of the fifth metacarpal.

There are seven interosseous muscles, all innervated by the ulnar nerve (Figure 268-5). The three palmar and four dorsal interossei lie between the metacarpal bones and originate from them. The palmar interosseous muscle and the palmar portion of the dorsal interosseous muscle have an insertion into the extensor hood.
The palmar interosseous muscle adducts the index, ring, and small finger to the midline, which is designated as the middle finger. The dorsal portion of the dorsal interosseous muscle has a tendinous insertion into the base of the proximal phalanx. The dorsal interosseous muscles abduct the fingers away from the midline.

The lumbrical muscles (Figure 268-3) do not attach to bone. They arise from the FDP tendons in the palm, course radially near the MCP joints, and attach to tendons or expansions, reinforcing the interosseous lateral band on the radial side of the digit. They flex the MCP joints while extending the IP joints. The median nerve innervates the radial two lumbricals, and the ulnar nerve innervates the ulnar two. The lumbricals flex the MCP joint and extend the IP joints of the index to the small fingers. Lumbrical muscles also play a critical role coordinating the flexor and extensor systems of the digits.

EXTENSOR AND FLEXOR TENDONS

The extensor tendons course over the dorsal side of the forearm, wrist, and hand (Figure 268-4). Nine extensor tendons pass under the extensor retinaculum and separate into six compartments. In the dorsum of the hand, the extensors digitorum communis are connected by juncturae (Figure 268-6). Based on this anatomy, finger extension may still be possible with a complete tendon laceration that is proximal to the juncture. In the finger, the extensor mechanism divides into a central slip that attaches to the middle phalanx and into two lateral bands that join with the tendons of the lumbral and interosseous muscles, which then attach to the dorsal base of the distal phalanx as the terminal tendon.

FIGURE 268-6.
Dorsal view of the hand showing juncturae tendinum. EPL, extensor pollicis longus; EPB, extensor pollicis brevis; ECRL, extensor carpi radialis longus; APL, abductor pollicis longus; ECRB, extensor carpi radialis brevis; EIP, extensor indicis proprius; EDC, extensor digitorum communis; EDQ, extensor digitorum quinti; ECU, extensor carpi ulnaris.
The flexor tendons (flexor carpi radialis, flexor carpi ulnaris, and palmaris longus) course over the volar side of the forearm, wrist, and hand, and primarily flex the wrist. The remaining nine tendons (four FDP, four FDS, and the FPL) pass through the carpal tunnel (Figure 268-1). The FPL goes to the base of the distal phalanx of the thumb. The other four digits have two tendons each (Figure 268-2). The FDS inserts into the volar, proximal half of the middle phalanx and flexes all the joints it crosses, including the proximal interphalangeal (PIP) joint and MCP joints. The FDP runs deep to the FDS until the level of the MCP joint, at which point it bifurcates. The FDP inserts at the volar base of the distal phalanx and acts primarily to flex the distal interphalangeal (DIP) joint as well as all the PIP and MCP joints. Unlike the extensor tendons, the flexor tendons are enclosed in synovial sheaths, making them prone to deep space infections.

**VASCULAR SUPPLY**

The hand and digits are perfused by the radial and ulnar arteries. The radial artery forms the deep palmar arch, whereas the ulnar artery forms the superficial palmar arch. The common digital arteries (in the second, third, and fourth web spaces) arise from the superficial palmar arch (Figure 268-7) and provide blood supply to the fingers. The blood supply to the thumb arises from the princeps pollicis, which is the radial artery as it turns into the palm. The radialis indicis, which is on the radial side of the index finger, arises from the radial artery or the princeps pollicis.
NERVE SUPPLY

The radial, ulnar, and median nerves innervate the hand (Figure 268-8). In the hand, the median and ulnar nerves have mixed motor and sensory function. The superficial radial nerve (C5-T1) provides sensation to the dorsal radial aspect of the hand. The ulnar nerve (C7-T1) supplies sensory function to the small finger and the ulnar volar half of the ring finger and motor function to the hypothenar muscles, ulnar two lumbricals, interossei, adductor pollicis, and deep head of the flexor pollicis brevis. The median nerve (C5-T1) supplies sensory function to the thumb, index, middle, and radial volar half of the ring fingers, and motor function to the abductor pollicis brevis, opponens pollicis brevis, and superficial head of flexor pollicis brevis. As the digital nerves course across the palm, they are superficial structures and thus are easily injured. Digital nerve sensation and two-point discrimination should be routinely assessed when evaluating lacerations of the palm (Figure 268-8). Normal two-point discrimination is 5 mm. Consult a hand specialist if the extent of injury is uncertain. In the digits, the digital nerves divide into volar and dorsal branches to supply sensation.
to the fingers. Knowing the location of these nerves is important to properly perform a digital block (Figure 268-3, cross-sectional view).

**FIGURE 268-8.**
The cutaneous nerve supply in the hand. DCU = dorsal cutaneous branch of ulnar nerve; M = median nerve; PCM = palmar cutaneous branch of median nerve; R = superficial radial nerve; U = ulnar nerve.

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**FIGURE 268-9.**
Relationship of nerves, arteries, tendons, and muscles at the level of the metacarpals.
CLINICAL FEATURES

Do not allow a visually striking hand injury to delay the identification and treatment of other potentially life-threatening injuries. After hemorrhage control, assessment involves a detailed history, general hand examination, testing of nerves and tendons, anesthesia, and direct wound inspection. Compare with the uninjured hand, especially to identify partial motor or sensory deficits.

HISTORY

The history should include the time and cause of injury as well as the position of the hand at the time of injury. Ask about the possibility of associated crush, burn, injection, or chemical exposure. When applicable, determine the type and amount of chemical to which the patient was exposed. Document the patient's occupation, avocations, prior hand injuries, and hand dominance to determine the functional impact of the injury.
PHYSICAL EXAMINATION

Detail the extent of injury by documenting the vascularity, status of the skin, posture of the fingers, and presence of deformity or active bleeding. Ask the patient to demonstrate the hand position at the time of injury. Injuries with the digits in flexion may result in retraction of the cut end of the tendon when the digit is examined in extension. Check bilateral grip strength. Compare motor, sensory, and tendon function of both hands to assess baseline function. Test range of motion and strength against resistance. Have the patient make a clenched fist to observe the orientation and rotation of the middle and distal phalanxes. All phalanges should be oriented parallel to each other with the nails positioned in the same plane and be pointing toward the scaphoid when the fist is clenched. Circulation is assessed by regional pulses and capillary refill.¹ Doppler assessment can also help assess digital artery flow.

NERVE TESTING

To test the median nerve, have the patient flex the IP joint of the thumb against resistance, which tests FPL function. Alternatively, hold the index or middle finger PIP and MCP joints in extension and have the patient flex the DIP joint, which tests FDP function of the index and middle fingers. The "OK" sign will reveal the ability to flex the IP joint of the thumb and the DIP joint of the index finger. To test the motor branch of the median nerve, position the thumb in palmar abduction with the palm up. Have the patient resist a force directing the thumb toward the palm, and assess the motor power while palpating the belly of the abductor pollicis brevis muscle to ensure it is contracting. It is important to note that a laceration at the level of the wrist or distal forearm may have intact FDP function of the index and middle fingers and FPL function to the thumb because these muscles have been innervated at the proximal forearm. A median nerve injury at the level of the wrist or distal forearm can only be determined by examining two-point discrimination in the three and a half radial digits or motor branch integrity to the thenar muscles.

To assess ulnar nerve integrity, have the patient spread the fingers apart (finger abduction) and assessing the motor power by resisting a force pushing the index and small fingers to midline. Alternatively, have the patient cross the fingers. To test thumb adduction (the ulnar nerve innervates the adductor pollicis muscles), have the patient hold a piece of paper with the volar pulp of the thumb against the radial side of the PIP joint of the index finger. If the patient can maintain the key pinch of the paper against resistance then the adductor pollicis is relatively strong. If the patient cannot hold the paper and uses the FPL and flexes the IP joint to compensate for the weak adductor pollicis this is a positive Froment's sign and indicates ulnar nerve pathology. All these reviewed maneuvers for the ulnar nerve test intrinsic muscles so that an ulnar nerve injury at the level of the wrist would be revealed by these test maneuvers.

To test the radial nerve, have the patient hyperextend the finger MCP joints against resistance, which will test the extensor digitorum communis tendons. One way to test this is to have the patient put the palm on a table, with fingers flat and hyperextended, and then lift each digit straight up and extend up from the Table while keeping the palm flat. Finger resistance can also be checked in this extended, upright position. During this maneuver, the finger MCP joints in hyperextension because the interossei extend the IP joints of the fingers (but flex the MCP joints), and failure to keep the digit in full extension can mislead...
the examiner into believing the radial nerve is intact. The interossei cannot hyperextend the finger MCP joints. By extending the thumb against resistance, the extensor pollicis longus integrity is confirmed. If a patient has a posterior interosseous nerve (which innervates the majority of the extensor muscles) palsy, the patient will be unable to hyperextend his or her fingers, but may be able to extend the wrist in a radial direction because the extensor radialis longus and extensor radialis brevis are innervated by the radial nerve proper before the posterior interosseous nerve branches.

**Sensation** is determined by two-point discrimination. **Normal two-point discrimination is 5 mm at the volar fingertips. Older patients may have 6 mm of two-point discrimination.** Compare both injured and contralateral fingers to establish a reasonable baseline, because patients may have preexisting compressive neuropathies such as carpal and cubital tunnel syndrome or previous nerve injuries. Examine the radial and ulnar sides of each finger to determine which digital nerve is injured. Hand specialists recommend repeating two-point discrimination testing two to four times on each side of the digit, because patients can guess sensation correctly by chance. At least 80% accuracy is considered acceptable. Less than 80% or indeterminate accuracy suggests the possibility of digital nerve injury. A sensory deficit also implies a potential digital artery laceration because of the close proximity of the two.

**TESTING OF TENDONS**

Assess full range of motion of each tendon against resistance and compare with the uninjured side. It is important to test resistance because **up to 90% of a tendon can be lacerated with preservation of range of motion without resistance.** In addition, the juncturae tendinum contributes to digital extension, so patients with lacerations to the extensor digitorum communis may be able to extend the digit but may not have the same motor power. **Pain along the course of the tendon during resistance testing suggests a partial laceration even if strength appears adequate.** Test FDP function by checking flexion of the DIP joint against resistance while holding the PIP and MCP joints in extension. Test the FDS by having the patient flex the PIP joint against resistance while the remaining fingers are held in full extension. When the rest of the fingers are in extension, the FDP of the tested finger cannot fire and the FDS function is isolated. If the test is not performed this way, PIP joint flexion may be due to the FDP because this tendon also traverses the PIP joint, whereas the FDS does not.

To determine whether the central slip is intact, perform the **Elson's test.** Hold the PIP joint of the affected finger in flexion (therefore tightening the central slip and loosening the lateral bands) and ask the patient to extend the finger at the PIP. The examiner should resist extension; if the DIP is loose, then Elson's test is negative, meaning the central slip is intact and the extension force is being transmitted to the central slip. If the DIP is rigid and the PIP does not extend, Elson’s test is positive, meaning the central slip is not intact and the extension force is being transmitted through the lateral bands to the terminal tendon to the DIP joint. The contralateral finger should be examined. Sometimes the patient can overpower the examiner and should be asked to decrease the extension force on the finger. Lastly, if the patient resists PIP flexion due to pain, a digital block can be placed and the test repeated.
ANESTHESIA AND DIRECT WOUND EXAMINATION

Anesthesia and direct wound inspection are necessary because partial tendon lacerations or intra-articular injuries are not always readily apparent. Perform the initial motor and sensory exam before anesthesia. **If pain limits the motor exam, a digital block can be performed and then motor function reassessed.** A bloodless field can be facilitated by milking the digit proximally and then applying a local tourniquet or Penrose drain around the base of the digit. The tourniquet should not be stretched to more than 150% of its length and can be held in place with a hemostat. The digit can be milked by wrapping another Penrose drain circumferentially around the entire digit, going from distal to proximal, or by reconfiguring a 4 × 4-inch gauze dressing into a narrow band and wrapping that circumferentially around the entire digit. Only moderate compression should be used to avoid compression injury to the digit. **Do not leave the tourniquet in place for >20 minutes.** Irrigate contaminated wounds copiously with normal saline, and administer antibiotics. Cephalosporins are often the first choice, but tailor antibiotic selection to the particular contaminant. Administer **tetanus toxoid** as needed.

RADIOGRAPHS, CONSULTATION, AND DISPOSITION

Radiologic evaluation should include at a minimum posteroanterior (PA), lateral, and oblique projections of the hand. Similar projections are used for the digits, except that the radiographic beam is centered over the affected digit(s), so that true PA and lateral views should be obtained of the affected digit. Actual or suspected injuries of tendons and nerves should be referred to a hand specialist. Whether consultation is provided in the ED or in follow-up (1 to 3 days) depends on local resources. Injuries requiring immediate and delayed follow-up by a hand surgeon are listed in **Tables 268-1 and 268-2,** respectively.

**TABLE 268-1**

**Immediate Hand Surgery Consultation Guidelines**

- Vascular injury with signs of tissue ischemia or poorly controlled hemorrhage
- Irreducible dislocations
- Grossly contaminated wounds
- Severe crush injury
- Open fracture
- Compartment syndrome
- High-pressure injection injury
- Hand/finger amputation
TABLE 268-2
Delayed Hand Surgery Consultation Guidelines

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensor/flexor tendon laceration</td>
<td>(if not repaired in ED)</td>
</tr>
<tr>
<td>Flexor digitorum profundus rupture (closed)</td>
<td>(Jersey finger)</td>
</tr>
<tr>
<td>Extensor digitorum rupture</td>
<td>(mallet finger)</td>
</tr>
<tr>
<td>Nerve injury</td>
<td></td>
</tr>
<tr>
<td>Closed fractures</td>
<td></td>
</tr>
<tr>
<td>Dislocations</td>
<td></td>
</tr>
<tr>
<td>Ligamentous injuries with instability</td>
<td></td>
</tr>
</tbody>
</table>

Table 268-3 provides guidelines for immobilization and follow-up for specific hand injuries referred for delayed hand surgery evaluation. Often, the skin can be closed and the hand splinted in the position of function. The wound can be extended and explored at follow-up, with definitive repair performed by the hand specialist. Most hand specialists prefer to do definitive repair of the acute injuries as soon as possible so patients should be informed to seek evaluation immediately and not in 2 weeks, as is often instructed. Also, some diagnoses may be missed in the acute stage when patients are in pain and a thorough exam is difficult. Thus, early referral to a hand specialist verifies the diagnosis and can detect other injuries. Although most injuries involving <20% of the tendon are not surgically repaired, hand specialist follow-up and rehabilitation are still necessary to accurately determine the extent of injury, minimize scarring and tendon contraction, and minimize neuroma formation.
<table>
<thead>
<tr>
<th>Injury</th>
<th>Splint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ligamentous injuries</strong></td>
<td></td>
</tr>
<tr>
<td>Thumb MCP ulnar collateral</td>
<td>Thumb spica, IP free to flex</td>
</tr>
<tr>
<td>ligament rupture</td>
<td></td>
</tr>
<tr>
<td>Partial tears</td>
<td>Thumb spica (presurgical repair)</td>
</tr>
<tr>
<td>Complete or equivocal</td>
<td>Thumb spica (presurgical repair)</td>
</tr>
<tr>
<td><strong>Tendon injuries</strong></td>
<td></td>
</tr>
<tr>
<td>Mallet finger</td>
<td>Dorsal splint, full extension at DIP</td>
</tr>
<tr>
<td>Flexor tendon laceration</td>
<td>Dorsal splint, 30-degree wrist flex, 70-degree MCP flexion, 30- to 45-degree PIP flexion (presurgical repair)</td>
</tr>
<tr>
<td><strong>Dislocations</strong></td>
<td></td>
</tr>
<tr>
<td>DIP joint</td>
<td>Dorsal splint, full extension</td>
</tr>
<tr>
<td>PIP joint</td>
<td></td>
</tr>
<tr>
<td>Stable/postreduction</td>
<td>Dorsal splint, 30-degree PIP flexion</td>
</tr>
<tr>
<td>Unstable/postreduction</td>
<td>Dorsal splint, 30-degree PIP flexion</td>
</tr>
<tr>
<td>MCP joint</td>
<td>Buddy-taping</td>
</tr>
<tr>
<td>Carpometacarpal joint</td>
<td>Dorsal-volar splint</td>
</tr>
<tr>
<td>Thumb IP joint</td>
<td>Dorsal splint, full extension</td>
</tr>
<tr>
<td>Thumb MCP joint</td>
<td>Thumb spica</td>
</tr>
<tr>
<td><strong>Fractures</strong></td>
<td></td>
</tr>
<tr>
<td>Distal phalanx</td>
<td>Volar or hairpin splint not immobilizing PIP</td>
</tr>
<tr>
<td>Injury</td>
<td>Splint</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Middle/proximal phalanx</td>
<td></td>
</tr>
<tr>
<td>Stable/nondisplaced</td>
<td>Buddy taping/dynamic splinting</td>
</tr>
<tr>
<td>Unstable/displaced</td>
<td>Radial/ulnar gutter, 90-degree MCP flexion, &lt;15- to 20-degree PIP flexion, &lt;5- to 10-degree DIP flexion</td>
</tr>
<tr>
<td>Thumb proximal phalanx</td>
<td>Thumb spica</td>
</tr>
<tr>
<td>Metacarpal</td>
<td></td>
</tr>
<tr>
<td>Index, middle</td>
<td>Radial gutter, 20-degree wrist flexion, 90-degree MCP flexion, PIP left mobile</td>
</tr>
<tr>
<td>Ring, small</td>
<td>Ulnar gutter, 20-degree wrist flexion, 90-degree MCP flexion, PIP left mobile</td>
</tr>
<tr>
<td>Thumb metacarpal</td>
<td></td>
</tr>
<tr>
<td>Extra-articular</td>
<td>Thumb spica</td>
</tr>
<tr>
<td>Intra-articular</td>
<td>Thumb spica for initial immobilization (presurgical repair)</td>
</tr>
</tbody>
</table>

**Abbreviations:** DIP = distal interphalangeal; IP = interphalangeal; MCP = metacarpophalangeal; PIP = proximal interphalangeal.

**Note:** Hairpin splint: metal backed splint with foam padding; dynamic splint: spring-loaded splint that allows some motion at unaffected joints while protecting the injured joint, usually available from a hand surgeon or occupational therapist.

For patients with hand or digit lacerations that are sutured in the ED, and when there is no suspicion of neurovascular or tendon injury, follow-up evaluation and suture removal in the ED should always include repeat hand examination to make sure that significant injuries have not been missed.

**FLEXOR TENDON INJURIES**

The most common cause of flexor tendon injury is laceration. Flexor tendon lacerations can be subtle. A hand surgeon should repair all flexor tendon lacerations. Temporary stabilization and loose closure may be performed in the ED but should occur within 12 hours. Definitive treatment can occur up to 4 weeks after the injury.
injury but as soon as possible is best. In general, flexor tendon lacerations of <25% do not need to be repaired, but it is difficult to make this assessment in the ED. A distal-to-proximal five-zone (I to V) classification system for flexor tendon injuries has been developed based on location, treatment considerations, and prognosis (Figure 268-10).²

**Figure 268-10.**
Flexor tendon zones and no man’s land.

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**ZONE I**

Zone I is distal to the insertion of the FDS so that injuries involve the FDP alone. Patients with such injuries lose flexion at the DIP joint.
Zone II involves the portion of the digital canal occupied by both FDS and FDP tendons (Figure 268-5). This zone is known as no man’s land because injury in this zone has historically resulted in poor outcomes. This is due to the narrow fibro-osseous tunnel that consists of the metacarpals/phalanges. Lacerations in this zone are common, and partial lacerations are more common than complete injuries.

ZONE III

Zone III extends from the distal edge of the carpal tunnel to the proximal edge of the flexor tendon pulley system. The lumbrical muscles originate from the FDP tendons in this region. Outcomes are generally favorable.

ZONE IV

Zone IV is at the level of the carpal tunnel. The area must be explored carefully because many vital structures traverse this region. Isolated injuries are the exception.

ZONE V

Zone V involves injuries to tendons proximal to the carpal tunnel. Injuries here tend to be severe and often involve multiple tendons as well as the median or ulnar nerve (i.e., "spaghetti wrist"). Examine and test all major structures.

EXTENSOR TENDONS

The extensor tendons are the most common site of tendon injuries because of the superficial nature of the tendons on the dorsum of the hand. A separate zone classification system (I to VIII) for extensor tendon injuries has been developed for assessing injury patterns, repair techniques, and rehabilitation (Figure 268-11). There is growing opinion that extensor tendon injuries should now be repaired operatively as well, although ED repair has often been the standard of care. In general, extensor tendon lacerations <25% do not need repair.

FIGURE 268-11.
Extensor tendon zones of the hand. T = thumb.
EXTENSOR ZONE I

Zone I involves the area over the distal phalanx and DIP joint. Injury can occur from blunt or sharp trauma. Complete laceration or rupture of the tendon at this level will result in the inability to extend the DIP joint. This injury is often called a mallet finger (Figure 268-12), and it is the most common tendon injury in athletes. This injury has been classified as type I if there is tendon-only rupture, type II if there is a small avulsion fracture, and type III if >25% of the articular surface is involved. Type I can be treated with the DIP joint immobilized in continuous full extension for 6 to 10 weeks. For the best outcome, no flexion of the DIP joint is
permitted for the duration of splinting. Thus, instruct patients not to take off the splint. If they do remove the splint to clean the finger and the splint, the DIP should be held in extension. The DIP **cannot** be allowed to fall into flexion. Splints for the mallet finger can be a Stax or aluminofoam splint as long as the splint holds the DIP in full extension (*Figure 268-13*).

**FIGURE 268-12.**  
A. Mallet finger. B. Clinical appearance.

**FIGURE 268-13.**  
A and B. Splinting for mallet finger.
Type II injuries can be treated the same way if on x-ray the splinted finger in extension shows congruency with the rest of the noninjured articular surface of the distal phalanx on the distal articular surface of the middle phalanx. Other indications for surgery include an open injury and >30% to 50% articular fracture involvement. Chronic untreated mallet finger may result in a swan-neck deformity (Figure 268-14). This occurs when the lateral bands are displaced dorsally, resulting in increased extension forces on the PIP joint.

FIGURE 268-14.
Swan neck deformity.

EXTENSOR ZONE II

Zone II involves the area over the middle phalanx. Injuries are usually a result of laceration. Injuries to this area are treated similarly to zone I injuries.

EXTENSOR ZONE III

Zone III involves the area over the PIP joint. The central tendon is the most commonly injured structure. Complete disruption of the central tendon may result in the volar displacement of the lateral bands, causing them to be flexors along with the unopposed FDP. Additionally, the extensor hood retracts, causing extension of the DIP joint, resulting in the boutonnière deformity (Figure 268-15). Controversy exists
regarding whether treatment of zone III injuries should be conservative or operative. Closed injuries are initially treated with the PIP joint immobilized in continuous extension for 5 to 6 weeks and should be followed closely by a hand specialist.

FIGURE 268-15.
Boutonnière deformity.

EXTENSOR ZONE IV

Zone IV involves the area over the proximal phalanx. These injuries have clinical findings similar to zone III injuries. These injuries are often less likely to have long-term morbidity because the joint is not involved and the tendon at this level is broad and flat.

EXTENSOR ZONE V

Zone V involves the area over the MCP joint. Open injuries to this area should be considered human bites until proven otherwise. Wounds from human bites should have delayed repair following hospital admission for a course of broad-spectrum IV antibiotics. This injury may require operative washout. Clean, nonbite wounds can be repaired primarily using mattress sutures to reapproximate tendon edges.

EXTENSOR ZONE VI

Zone VI involves the area over the dorsum of the hand. Because the tendons in this area are so superficial, even minor-appearing lacerations may be associated with one or more tendon injuries. If the laceration is proximal to the juncturae tendineae, the patient may be able to extend the involved MCP joint, because
extensor forces are transmitted to the juncturae from adjacent extensor tendons. Injuries to zones VI, VII, and VIII typically require advanced suture techniques.

EXTENSOR ZONE VII

Zone VII involves the area over the wrist. Repair can be difficult because of the presence of the extensor retinaculum. This thick, fibrous structure on the dorsum of the wrist contains 12 extensor tendons and six synovial-lined retinacular compartments. Due to the anatomic complexity of this region, operative repair is needed.

EXTENSOR ZONE VIII

Zone VIII involves the area of the distal forearm. Injuries to this area require a thorough exploration to identify all injured structures. The tendons frequently retract into the forearm and must be retrieved and repaired. After repairs in zones V through VII, splinting should occur with the wrist in 15-degree extension, the MCP joint in 15-degree flexion, and the IP joint in 15-degree flexion in the involved and adjacent digits.

LIGAMENTOUS INJURIES AND DISLOCATIONS

Soft tissue injuries to the hand are extremely common. Accurate diagnosis and treatment are important to avoid complications such as joint luxation, loss of motion, chronic pain, and deformity.

DISTAL INTERPHALANGEAL JOINT

Dislocations of the DIP joint are uncommon because of the firm attachments of the skin and subcutaneous tissue to the underlying bone by osteocutaneous fibers. Additional stability is provided by the flexor and extensor tendons. When dislocations do occur, they are usually dorsal. Longitudinal traction and hyperextension followed by direct dorsal pressure to the base of the distal phalanx usually accomplish reduction. Attempts at reduction should be made after a digital nerve block or other means of anesthesia has been performed. Irreducible cases may be due to the entrapment of an avulsion fracture, the profundus tendon, or volar plate.

PROXIMAL INTERPHALANGEAL JOINT

Dislocations of the PIP joint are common hand injuries. The mechanism is usually due to axial load and hyperextension. Dorsal dislocation occurs when the volar plate ruptures. Lateral dislocations occur when one of the collateral ligaments ruptures with at least a partial avulsion of the volar plate from the middle phalanx. The digit is usually ulnarily deviated because the radial collateral ligament is six times more likely than the ulnar collateral ligament to rupture. Volar dislocations are rare. Dorsal dislocations are reduced in the same manner as dorsal DIP joint dislocations. Active motion and strength should be tested following reduction. If testing is normal, splint the joint at 30-degrees of flexion for 3 weeks. If the joint is irreducible or there is evidence of complete ligamentous disruption, operative repair is required.
**METACARPOPHALANGEAL JOINT**

Dislocations of the MCP joint are usually due to hyperextension forces that rupture the volar plate, causing dorsal dislocation. Subluxation is more common than dislocation. In subluxation, the joint appears to be hyperextended 60 to 90 degrees, and the articular surfaces are still in contact. Reduction here does not involve hyperextension because it might convert a subluxation into a complete dislocation. Reduction is performed by flexing the wrist to relax the flexor tendon and then applying pressure over the dorsum of the proximal phalanx in a distal and volar direction. After reduction, splint the MCP joint in flexion. Multipart dislocations appear less deformed because of the number of disrupted structures. Because the volar plate is interposed in the MCP joint space, closed reduction is usually not possible. Volar dislocations are rare and usually require operative reduction.

**CARPOMETACARPAL JOINT**

Dislocations of the CMC joint are uncommon because the joint is supported by strong dorsal, volar, and interosseous ligaments and is reinforced by the broad insertions of the wrist flexors and extensors. The cause is usually a result of high-speed mechanisms such as motor vehicle crashes, falls, crushes, or clenched fist trauma. If a dislocation occurs, it is usually dorsally oriented and associated with fracture(s). Reduction of dorsal CMC joint dislocations can be attempted after regional anesthesia is administered. Traction and flexion with simultaneous longitudinal pressure on the metacarpal base should reestablish normal anatomic alignment. Early referral after reduction is needed to determine if further fixation is needed. Volar CMC joint dislocations are exceedingly rare and should be referred to a hand specialist.

**THUMB INTERPHALANGEAL JOINT**

Dislocations of the thumb IP joint are rare but, if present, are usually open. The mechanism is typically hyperextension with rupture of the volar plate. Reduction is similar to that of the IP joints of the other digits. After reduction, the joint should be immobilized in 15 to 20 degrees of flexion for 3 weeks.

**THUMB METACARPOPHALANGEAL JOINT**

Dislocations of the MCP joint of the thumb are usually dorsal and result from a hyperextension force causing rupture of the volar plate. The dislocation may be simple or complex. Reduction, after radial nerve block, is accomplished with pressure directed distally on the base of the proximal phalanx with the metacarpal flexed and abducted.

**THUMB METACARPOPHALANGEAL (ULNAR) COLLATERAL LIGAMENT RUPTURE**

Rupture of the ulnar collateral ligament (gamekeeper's thumb, skier's thumb) occurs when the mechanism causes radial deviation (abduction) of the MCP joint. The tear usually occurs at the insertion into the proximal phalanx. Often significant injury to the dorsal capsule and volar plate occurs. Hand surgery referral is expected complete tears of the ulnar collateral ligament of the thumb, signs of which are pain, ecchymosis of the thumb MCP, and weakness of pinch. The diagnosis is made with
stress testing of the ulnar collateral ligament. The examiner tests the thumb MCP joint, both in full extension and 30-degree flexion, by stabilizing the metacarpal with one hand while applying lateral (radial) stress on the proximal phalanx with the other. More than 30 to 35 degrees of radial angulation or 10 to 15 degrees more than the contralateral thumb indicates complete rupture and requires surgical consultation. If patients are discharged from the ED, a thumb spica splint should be applied and urgent orthopedic follow-up arranged. Repair is best accomplished within 1 week. Radial collateral ligament rupture is not as common, and the mechanism is forced adduction. Examination with the same parameters applied in the ulnar direction is used to make the diagnosis of a complete radial collateral ligament rupture.

THUMB CARPOMETACARPAL JOINT

Isolated thumb CMC joint dislocation is rare compared with the more common Bennett's fracture dislocation (see below). These are easy to reduce but unstable after reduction. After reduction, a thumb spica splint should be applied. These injuries should have a surgical referral for a decision on operative repair.

FRACTURES

DISTAL PHALANX

Fractures of the distal phalanx usually result from crush or shearing forces. The fractures can be classified as tuft, shaft, or intra-articular. Tuft fractures can be associated with nail bed lacerations. Fractures at the base may be associated with flexor or extensor tendon involvement. Generally, fractures of the distal phalanx are treated as soft tissue injuries with protective splinting.

PROXIMAL AND MIDDLE PHALANX

The proximal phalanx has no tendinous attachments, so fractures frequently result in apex volar angulation from the forces of the extensor and interosseous muscles. For the middle phalanx, the FDS tendon inserts on the proximal volar half and the extensor tendon inserts at the proximal base. Therefore, fractures at the base of the middle phalanx demonstrate apex dorsal angulation, and fractures at the neck result in apex volar angulation. A direct blow mechanism usually causes a transverse or comminuted fracture, whereas a twisting mechanism will more often result in a spiral fracture. Most often, such fractures are stable and nondisplaced and can be treated with early protected motion by buddy taping. Unstable fractures amenable to closed reduction can be splinted from the MCP to the DIP joint with the MCP joint in 70 degrees of flexion and the IP joints in extension. Midshaft transverse fractures, spiral fractures, and intra-articular fractures often require internal fixation.

METACARPAL (SECOND TO FIFTH) FRACTURES

The second and third metacarpals are relatively immobile, and fractures require anatomic reduction. The ring and fifth metacarpals have 15- to 20-degree anteroposterior motion, which allows for some compensation for malunion. Metacarpal fractures are categorized as head, neck, shaft, or base fractures.
The presence of a metacarpal fracture should prompt close evaluation of the associated CMC joint, because CMC joint dislocation often accompanies these fractures and is often missed at the initial presentation.6

METACARPAL HEAD FRACTURES

Fractures of the metacarpal head are usually caused by a direct blow, crush, or missile. These fractures are distal to the insertion of the collateral ligaments and are often comminuted. If a laceration is present, a human bite must be considered. Treatment consists of ice, elevation, and immobilization with referral to a hand surgeon.

METACARPAL NECK FRACTURES

Fractures of the metacarpal neck are usually caused by a direct impaction force. A fracture of the fifth metacarpal neck is often referred to as a boxer’s fracture. These fractures are usually unstable with volar angulation. Angulation of ≤20 degrees in the fourth and ≤40 degrees in the fifth metacarpal will not result in functional impairment. If greater angulation in these metacarpals occurs, reduction should be attempted. To perform the reduction, flex the wrist and the MCP joint. Apply slight force to the volar aspect of the affected metacarpal while distracting the phalanx away from the palm. Following splinting, patients may have residual cosmetic deformity (not prominent metacarpal head), but in most cases regain full function. The amount of angulation at the time of injury does not correlate with resultant cosmetic defects.7 With second and third metacarpal fractures, angulation of <15 degrees is acceptable. Splint metacarpal neck fractures with the wrist in 20-degree extension and the MCP joint flexed at 70 degrees. Fractures of the second or third metacarpal that are significantly displaced or angulated require anatomic reduction and surgical fixation.

METACARPAL SHAFT FRACTURES

A direct blow usually results in fractures in the metacarpal shaft region. Rotational deformity and shortening are more likely in shaft fractures than in neck fractures. If manipulative reduction is necessary, operative fixation is usually indicated.

METACARPAL BASE FRACTURES

Fractures at the base of the metacarpal are usually caused by a direct blow or axial force. They are often associated with carpal bone fractures. CMC joint subluxation or dislocation should be suspected with these injuries. Given the overlap of the bones and joints on the lateral radiograph, a CT scan may be needed to definitively rule out joint subluxation or dislocation. Fractures at the base of the fourth and fifth metacarpals can result in paralysis of the motor branch of the ulnar nerve, although this is rare.8

THUMB METACARPAL FRACTURES

Because of the mobility of the thumb metacarpal, shaft fractures are uncommon. Fractures usually involve
Extra-Articular Fractures

Extra-articular fractures are caused by a direct blow or impaction mechanism. The mobility of the CMC joint can allow for 30-degree angular deformity. Angulation greater than this requires reduction and a thumb spica splint for 4 weeks. Spiral fractures often require fixation.

Intra-Articular Fractures: Bennett's Fracture and Rolando's Fracture

Intra-articular fractures are caused by impaction from striking a fixed object.

**Bennett's fracture** is an intra-articular fracture with associated subluxation or dislocation at the CMC joint. The ulnar portion of the metacarpal usually remains in place ("constant fragment"). The distal portion usually subluxes radially and dorsally from the pull of the abductor pollicis longus and the adductor pollicis. Treatment is application of a thumb spica splint and orthopedic referral.

**Rolando's fracture** is an intra-articular comminuted fracture at the base of the metacarpal. The mechanism of injury is similar to Bennett's fracture but less common. Treatment includes a thumb spica splint and orthopedic consultation.

COMPARTMENT SYNDROME

Crush injury of the hand, with or without associated fracture, may result in compartment syndrome. Iatrogenic causes of compartment syndrome of the hand include extravasation of IV fluids or contrast media or arterial punctures. The involved compartments of the hand include the thenar, hypothenar, adductor pollicis, and four interossei muscles. Edema of tissues or hemorrhage within any of these compartments may lead to elevated pressures that result in tissue necrosis and subsequent loss of hand function due to contracture. Classic signs and symptoms of compartment syndrome typically include pain and paresthesias early, with paralysis and pulselessness occurring later in the course of the ischemic injury. **Hand compartment syndromes, however, may not be associated with paresthesias, and the extremely subtle motor deficits and difficulty in assessing response to passive stretch make the diagnosis more elusive than at other anatomic sites.** Pain, the most consistent clinical sign, is often described as deep, constant, poorly localized, and disproportionate to clinical findings. Physical examination findings suggestive of hand compartment syndrome include extreme swelling, the intrinsic minus position at rest (MCP joint extended with PIP joint slightly flexed), pain with passive stretch of the involved compartment muscles (interosseous: performed with MCP joint extended and PIP joint fully flexed with slight radial and ulnar deviation; thenar, hypothenar: performed by extension of MCP joint), and tense swelling of the affected compartment. Compartment pressure measurement is difficult and inexact in the relatively small compartments of the hand. The diagnosis is typically made on a clinical basis, not on actual compartment pressures.

In the setting of severe crush injury with signs and symptoms suggestive of compartment syndrome, immediately consult with a hand specialist to determine if emergency fasciotomy is indicated.
HIGH-PRESSURE INJECTION INJURY

The injection of certain substances under high pressures (often 2000 to 10,000 psi) into the soft tissues of the hand may initially appear benign but are actually true orthopedic emergencies. The operator of the high-pressure device typically attempts to test or clean the nozzle with the nondominant hand and inadvertently injects the substance. The initial dissipation of kinetic energy through the soft tissues of the hand and the subsequent chemical inflammation produce tissue edema and ischemia. The most commonly injected substances include grease, paint, hydraulic fluid, diesel fuel, paint thinner, and water. Paint, especially oil-based paint, triggers an intense inflammatory response that contributes to significant ischemic injury. The benign appearance of the small injection site in the immediate postinjection period is misleading, and historical information must dictate treatment and disposition decisions. With time, the digit becomes edematous, pale, and severely tender to palpation, suggesting ischemic injury. Pressure to areas surrounding the wound may express the injected substance. Plain radiographs of the injected hand and forearm provide valuable information, as radiopaque substances, such as lead-based paints or grease, or subcutaneous emphysema may delineate the extent of the injection. **Definitive treatment of high-pressure injection injuries is early surgical decompression and debridement of injected areas.** Obtain immediate hand surgery consultation, immobilize and elevate the affected hand, administer tetanus prophylaxis and broad-spectrum antibiotics, and provide adequate analgesia. Amputation rates following injection injury are as high as 30%, highlighting the need for rapid identification and proper treatment of the injury.

REFERENCES


