Extension of the fingers is a complex function carried out by simultaneous action of extrinsic and intrinsic muscles, as well as retinacular structures in the dorsum of the wrist, hand, and fingers that support and coordinate the action of the muscles. The extensor mechanism of the fingers is divided into topographic zones, which extend from the forearm to the distal phalanx. Magnetic resonance (MR) imaging shows in detail the musculotendinous and retinacular structures of the extensor apparatus. In the different extensor zones, MR imaging findings are similar to those seen macroscopically in anatomic sections.

Understanding of and familiarity with the extensor anatomy of the hand and fingers by the radiologist is crucial for better assessment of pathologic conditions with MR imaging and optimization of this modality as a diagnostic tool. Extensor tendon injuries and tenosynovitis represent clinical situations in which knowledge of this anatomy is useful for the clinical radiologist.
Introduction

Several authors have described the usefulness of magnetic resonance (MR) imaging in assessing the anatomy and pathologic conditions of flexor tendons of the hand and fingers (1–7). However, there are few detailed descriptions of the appearance and disease states of the extensor mechanism (8,9), which is arguably the most complex anatomic structure of the hand.

Finger extension involves simultaneous actions of both extrinsic and intrinsic extensor muscles. Extrinsic muscles originate in the elbow and forearm and include the following: extensor digitorum, extensor indicis, and extensor digiti minimi. The primary function of these muscles is extension of the metacarpophalangeal (MCP) and interphalangeal joints. The intrinsic muscles that originate and insert within the hand are the lumbrical and interosseous muscles. The function of these muscles is primarily to extend the interphalangeal joints and secondarily to contribute to flexion of the MCP joint. These groups of extrinsic and intrinsic muscles are coordinated by a series of stabilizing retinacular structures, which facilitate balanced transmission of muscular force. These structures are found in the dorsum of the carpum (extensor retinaculum), the hands (intertendinous connections), and the fingers (extensor hood, retinacular and triangular ligaments).

The aim of this article is to describe in detail the extensor anatomy as established with MR images and to correlate it with the findings derived from anatomic sectioning. To provide the background for understanding and predicting the results of injuries at any level, we have focused especially on making a systematic description by zones following the topographic classification most commonly used in orthopedics. The zones are as follows: extrinsic extensor muscles (zones VIII–X), wrist extensor compartments (zone VII), dorsum of the hand (zone VI), MCP joint level (zone V), proximal phalanx and proximal interphalangeal (PIP) joint (zones IV and III), and middle phalanx and distal interphalangeal (DIP) joint (zones II and I). The article includes anatomic drawings and photographs of dissected

Figure 1. Anatomy of the extensor apparatus. 
(a) Drawing of the hand (dorsal view) shows the main anatomic structures. 1 = extensor digitorum muscle, 2 = extensor digiti minimi muscle, 3 = extensor carpi ulnaris muscle, 4 = abductor pollicis longus muscle, 5 = extensor pollicis brevis muscle, 6 = extensor pollicis longus tendon, 7 = extensor indicis tendon, 8 = extensor carpi radialis longus muscle, 9 = extensor carpi radialis brevis muscle, 10 = intertendinous connections, 11 = extensor retinaculum, 12 = first dorsal interosseous muscle, 13 = abductor pollicis tendon, 14 = abductor digitii minimi muscle, 15 = sagittal band, 16 = central slip, 17 = lateral conjoined tendon, 18 = medial conjoined tendon, 19 = terminal tendon, 20 = triangular ligament. 
(b) Drawing of the hand (dorsal view) shows the zones of the extensor system according to the Verdan classification (10). This classification was developed to categorize the lesion findings. I = DIP joint, II = middle phalanx, III = PIP joint, IV = proximal phalanx, V = MCP joint, VI = dorsum of hand, VII = wrist extensor compartment, VIII = extrinsic extensor muscles.
specimens to allow a better understanding of these structures. Finally, we include a systematic description of extensor tendon injuries and of major tenosynovitis, which represent clinical situations in which knowledge of this anatomy proves to be extremely useful for the clinical radiologist.

**Materials and Methods**

Eight cadaveric specimens were immediately harvested and frozen at −28°C. The precise ages of the donors were unknown. The specimens were immersed in water for 8 hours. MR imaging was then performed with both a 0.35-T open system (Opart; Toshiba America, San Francisco, Calif) and a 1.5-T system (Excelart; Toshiba America). Dedicated coils for studying small parts of the limbs were used to maximize spatial resolution. Axial and sagittal T1-weighted imaging (repetition time msec/echo time msec = 644/20) and proton-density-weighted fast spin-echo imaging with spectral fat saturation (2,500/20) were performed with an imaging matrix of 192–208 × 256, a 7–9-cm field of view, four signals acquired, and a section thickness of 3–4 mm with no gap.

All specimens were refrozen, and a band saw (Mado Selekta 3) was used to cut them into 3.0-mm-thick slices along the axial and sagittal imaging planes. The slices were digitally photographed (Nikon D1X camera, Micro-Nikkor 105-mm lens, 2.8 f-stop). Anatomic slices were immersed in 70% alcohol for photographing. The photographs were correlated with the corresponding MR images by means of consensus of a musculoskeletal radiologist (J.A.C.) and two anatomists (P.G., O.F.).

**Anatomic Considerations**

The concept of anatomic zones is based on the characteristic anatomic features of the extensor tendon system and the specific findings at each lesion topography. Several classifications have been developed, although the Verdan system (10) is the one most widely accepted. This includes eight zones: Zone I is located at the level of the DIP joint, and zone VIII is located at the distal forearm (Fig 1). The odd zones are the joint areas. Some authors include two further zones for the intramuscular tendon (zone IX) and the muscle belly (zone X) (11).

For purposes of clarity, we begin the anatomic study and its assessment with MR imaging at the level of the extrinsic muscles of the forearm, then proceed distally until we reach the fingers, where the extrinsic and intrinsic muscles interact with retinacular structures to form the so-called extensor mechanism.

**Extrinsic Extensor Muscles (Zones VIII–X)**

The extensor muscles of the dorsal forearm consist of a surface group of five muscles and a deep group of four muscles (Fig 2). From radial to ulnar, the surface extensor group includes the extensor carpi radialis longus, extensor carpi radialis...
brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris. These muscles mainly originate from the posterior side of the lateral epicondyle and in a portion of the intermuscular septum. The extensor carpi radialis longus inserts on the dorsum of the base of the second metacarpal, the extensor carpi radialis brevis inserts on the dorsum of the base of the third metacarpal, and the extensor digitorum chiefly inserts on the dorsal side of the fingers. The extensor digiti minimi inserts on the small finger, and the extensor carpi ulnaris inserts on the dorsoulnar side of the base of the fifth metacarpal.

From radial to ulnar, the group of deep muscles consists of the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis. These muscles mainly originate in the midforearm in the interosseous membrane and cross the forearm in an oblique fashion, toward the radial aspect of the wrist. The abductor pollicis longus inserts on the radial base of the first metacarpal, the extensor pollicis brevis inserts on the base of the proximal phalanx of the thumb, the extensor pollicis longus inserts on the dorsal base of the distal phalanx of the thumb, and the extensor indicis inserts on the dorsal side of the index finger.

The physiologic cross-sectional area is proportional to the force generated by the muscle, whereas the length of the fiber is proportional to the excursion and speed of the contraction. Extrinsic finger extensor muscles have relatively long fibers and small physiologic cross-sectional areas; therefore, they are better designed for excursion and speed than for the generation of force (12).

These muscular masses can be well visualized with MR imaging in all three spatial planes. However, axial sections are ideal since they allow us to differentiate the muscles and correlate them with neighboring structures. The latter will sometimes make muscle identification easier. Specific surface muscles can often be viewed thanks to the existence of intermuscular septa and the surrounding adipose tissue (Fig 3). However, identification of specific deep extensor muscles is more difficult.

**Figure 3.** Axial anatomic slice (a) and axial T1-weighted MR image (b) obtained at the proximal one-third of the forearm show the extensor muscles. 1 = extensor carpi radialis longus and brevis, 2 = extensor digitorum, 3 = extensor digiti minimi, 4 = extensor carpi ulnaris, 5 = abductor pollicis longus, 6 = extensor pollicis brevis, 7 = extensor pollicis longus, 8 = extensor indicis, 9 = brachioradialis.
Figure 4. Axial anatomic slice (a) and corresponding T1-weighted MR image (b) obtained at the distal one-third of the forearm and (c, d) sequential axial T1-weighted MR images obtained at the first intersection show the extensor tendons. The first intersection is produced when the abductor pollicis longus and extensor pollicis brevis (1) cross over the extensor carpi radialis longus (2) and extensor carpi radialis brevis (3). 4 = extensor pollicis longus, 5 = extensor indicis, 6 = extensor digitorum, 7 = extensor digiti minimi, 8 = extensor carpi ulnaris.

(with both MR images and anatomic axial sections) because of their oblique path, their common origin, and the lack of consistent intermuscular septa. There are two intersections between the deep and surface extensor layers; the proximal intersection, which is located at this level, is found where the abductor pollicis longus and extensor pollicis brevis tendons cross over the extensor carpi radialis tendons, proximal to the extensor retinaculum (Fig 4).
Wrist Extensor Compartments (Zone VII)

The extensor retinaculum at the dorsal aspect of the wrist establishes a mechanism that strongly restricts the extensor tendons. This retinaculum is derived from the deep parts of the antebrachial fascia and consists of two layers: supratendinous and infratendinous (Fig 5). The infratendinous layer is limited to the most ulnar area (13), and the supratendinous layer projects six longitudinal vertical septa that insert onto the radius, producing six compartments where the extensor tendons run in the wrist. At this level, the tendons are lined by a synovial sheath to make them slide more easily. On axial MR images, the tendinous structures are clearly viewed in their corresponding compartments and appear as low-signal-intensity tubular structures. Furthermore, the retinaculum also appears on these sections as a fine, low-signal-intensity, linear structure that covers the tendons (Fig 5).

The first compartment contains the abductor pollicis longus and extensor pollicis brevis tendons. The floor is made up of the radial styloid process and the insertion of the brachioradialis muscle. The second compartment contains the extensor carpi radialis longus and extensor carpi radialis brevis tendons. Occasionally, more than two tendons are observed (14). The third compartment contains the extensor pollicis longus tendon before it crosses over the extensor carpi radialis longus and extensor carpi radialis brevis tendons, a detail that corresponds to the previously mentioned second intersection (Fig 6). These two compartments are separated by the Lister tubercle (dorsal tubercle). The fourth compartment is wide and contains the extensor digitorum tendons and, more deeply, the extensor indicis tendon. The fifth compartment is located above the distal radioulnar joint and contains the extensor digiti minimi tendon, which usually has two slips (Fig 7). The sixth compartment contains the extensor carpi ulnaris tendon and is located within an indentation along the dorsal aspect of the distal ulnar epiphysis.

Figure 5. Axial anatomic slice (a) and corresponding T1-weighted MR image (b) obtained at the proximal wrist show the extensor tendons inside the dorsal compartments (1st–6th). The tendons are fixed in the compartments by the extensor retinaculum, which is divided into a superficial part (arrowheads) and a deep part (arrow). The Lister tubercle (*) separates the second and third compartments.
Figures 6, 7. 

(6a, 6b) Axial anatomic slice (a) and corresponding T1-weighted MR image (b) obtained at the intercarpal joints show the second intersection. This intersection is produced when the extensor pollicis longus tendon (3) crosses over the extensor carpi radialis longus (1) and brevis (2) tendons. The extensor carpi radialis longus tendon may be divided into two or more slips (arrowheads). 

(6c) Axial anatomic slice (close-up view) shows the second intersection. 1 and 1’ = extensor carpi radialis longus tendons, 2 = extensor carpi radialis brevis tendon, 3 = extensor pollicis longus tendon.

(7) Axial anatomic slice (a) and corresponding sequential T1-weighted MR images (b) obtained at the distal radioulnar joint show the double tendon of the extensor digiti minimi (arrow).
Dorsum of the Hand (Zone VI)

The dorsum of the hand features greater anatomic variability because of tendinous multiplicity and the presence of connections between the different tendons. In most cases, there is more than one tendon for each finger between the wrist and the MCP joints (15). Furthermore, this multiplicity increases near the ulnar zone (16,17). The most frequent distribution pattern is as follows: a single extensor indicis tendon located ulnar to the extensor digitorum tendon of the index finger in the MCP joint; a single extensor digitorum tendon for the index finger; a single thick extensor digitorum tendon for the middle finger; a double extensor digitorum tendon for the ring finger; no extensor digitorum tendon for the little finger; and a double extensor digiti minimi tendon for the little finger. The most frequent variations (>10%) are a double extensor indicis tendon, a double or triple extensor digitorum tendon for the middle finger, a single or triple extensor digitorum tendon for the ring finger, and a single or double extensor digitorum tendon for the little finger (16,18).

Awareness of the variations and the multiplicity of the extensor tendons of the dorsum of the hand is crucial for adequate assessment of hand lesions. Moreover, this knowledge is very important in the event of a tendon transfer. However, although both axial and anatomic sections at MR imaging may demonstrate this multiplicity, it is extremely difficult to precisely identify the muscle group corresponding to each tendinous structure. This will be possible only with a thorough anatomic dissection. The different tendinous structures for each finger appear on MR images as low-signal-intensity structures that are tubular or flat (Fig 8).

Near the MCP joint, the extensor tendons are interconnected in the dorsum of the hand by intertendinous connections (connexus intertendineus) (19,20) (Fig 9). These connections create
space between the extensor tendons, redistribute their force, coordinate the extension, and stabilize the MCP joints (21). They also prevent independent extension of the fingers, although this is also due to the existence of a common muscle belly. From a clinical point of view, they are very important because they can act as a bridge masking tendinous lesions (22) and cause snapping by subluxation at the MCP joint (23).

There are three intertendinous connections, which exhibit frequent anatomic variations. First, A-type connections link the common extensor tendons of the index and middle fingers. They are typically fascial. The extensor indicis has no intertendinous connections. Second, B-type connections link the extensor tendons of the middle and ring fingers. These connections are more variable and usually have a ligamentous or tendinous morphology. Finally, C-type connections link the extensor tendons of the ring and little fingers. They have a tendinous morphology and a more transverse orientation.

The extensor digiti minimi often has intertendinous connections. The frequent lack of a common extensor tendon for the little finger is related to the multiplicity of tendons for the ring finger and to very thick C-type intertendinous connections. Thus, some authors have stated that this connection is actually a tendinous bifurcation or trifurcation of the extensor digitorum tendon for the ring finger (24) or a remnant of the extensor digitorum tendon for the little finger (16).

In our comparative study of axial MR images and axial anatomic sections, C-type intertendinous connections characteristically appeared as a tendinous structure located between the extensor tendons of the fourth and fifth fingers, adjacent to the MCP joint (Fig 10). We could not see these intertendinous connections on the coronal sections, probably because the structure was too thin and had an oblique anteroposterior orientation.

Figure 10. (a, b) Axial anatomic slice (a) and corresponding T1-weighted MR image (b), obtained at the distal dorsum of the hand, show the C-type intertendinous connections (arrow) to the extensor digiti minimi (arrowhead). (c) Sequential axial T1-weighted MR images show the direction of the C-type intertendinous connections (arrow) from the extensor digitorum for the fourth finger to the extensor digiti minimi.
MCP Joint Level (Zone V)

When the extensor tendon reaches the MCP joint, it links with the sagittal bands, one of the main elements of the extensor hood (Fig 11). Each sagittal band consists of a fibrous sheet that surrounds the MCP joint. It has a volar point of insertion next to the palmar plate and neighboring structures of the MCP joint, and a dorsal point of insertion into the extensor tendon (25). It has a triple function: to extend the proximal phalanx with the traction provided by the tendon, to stabilize the tendon at the dorsum of the joint, and to limit the proximal excursion of the tendon (8,26). On axial MR images, the sagittal bands appear as fine, low-signal-intensity, linear structures distributed circumferentially from the extensor tendon to the palmar plate (Figs 12, 13).

Figure 11. Drawing (a) and transilluminated anatomic specimen (b) (dorsal view) show the extensor apparatus of the index finger (removed from its location). 1 = extensor digitorum tendon, 2 = interosseous muscle, 2’ = lumbrical muscle, 3 = sagittal band, 4 = medial slip, 5 = central slip, 6 = lateral slip, 7 = medial conjoined tendon, 8 = lateral conjoined tendon, 9 = triangular ligament, 10 = terminal tendon, 11 = transverse fibers, 12 = oblique fibers, 13 = retinacular ligament.

Figure 12. Axial anatomic slice (a) and corresponding fat-suppressed proton-density–weighted MR image (b) obtained at the MCP joint show the circumferential distribution of the dorsal apparatus over the dorsum of the fingers. Arrows = sagittal band.
Distal to the sagittal bands, the transverse and oblique fibers appear as the initial contribution of the intrinsic muscles to the extensor mechanism (Figs 11, 14). On MR images, these fibers appear as fine, low-signal-intensity, linear structures surrounding the dorsum of the proximal phalanx. The intrinsic muscles comprise the lumbrical and interosseous groups.

Figure 13. (a, b) Axial anatomic slice (a) and corresponding fat-suppressed proton-density–weighted MR image (b) obtained at the MCP joint show the sagittal bands (arrows), which extend from the extensor digitorum tendon to the palmar plate. (c, d) Axial anatomic slice (close-up view) (c) and corresponding T1-weighted MR image (d) show the sagittal band (arrow). 1 = extensor digitorum tendon, 2 = palmar plate, 3 = flexor tendon sheath, 3' = flexor tendon, 4 = interosseous muscle, 5 = lumbrical muscle, III = third metacarpal bone, * = deep transverse metacarpal ligament. Note that the interosseous muscle is dorsal to the deep transverse metacarpal ligament and the lumbrical muscle is palmar to the ligament.

Figure 14. Anatomic slice (medial view) shows the MCP joint level of the third finger. In this area, the extensor digitorum tendon (1) receives the intrinsic contribution of the interosseous muscle (2). This contribution consists of the transverse fibers (3) and oblique fibers (4). 5 = deep transverse metacarpal ligament, 6 = sagittal band.

There are four lumbral muscles, which originate in the deep flexor muscles of the fingers, at the level of the middle palmar region of the hand. The four lumbral muscles reach the MCP joint at its radial aspect and run palmar to the deep transverse metacarpal ligament (Fig 12) and to the transverse axis of the joint, thus acting as flexors for the MCP joint. As can be seen in zone IV, they join the extensor mechanism (Fig 11) in a distal position and act as extensors of the interphalangeal joints. These are the only muscles with a tendinous origin and insertion (21).
There are seven interosseus muscles: three palmar and four dorsal (Fig 15) (27). The three palmar muscles have their origins at the second, fourth, and fifth metacarpals. The first of these muscles is located on the ulnar side of the metacarpal, whereas the other two are located on the radial side. Owing to their location, they act as adductors of the fingers, as well as flexors of the MCP joint and extensors of the interphalangeal joints.

The four dorsal interosseous muscles originate at the adjacent metacarpals: The first muscle is located on the radial side of the second metacarpal, the second muscle is located on the radial side of the third metacarpal, the third muscle is located on the ulnar side of the third metacarpal, and the fourth muscle is located on the ulnar side of the fourth metacarpal. These muscles are abductors of the fingers; just like the interosseous palmar muscles, they act as flexors of the MCP joint and extensors of the interphalangeal joints. The fifth finger does not have a dorsal interosseous muscle because abduction of this finger is carried out by the abductor digiti minimi muscle.

At the MCP joints, the interosseous muscles are located dorsal to the deep transverse metacarpal ligament (Fig 12) but palmar to the transverse axis of the joint. The insertions of these muscles occur at three different levels: deep insertions on the lateral tubercle of the proximal phalanx, surface proximal insertions that contribute to formation of both the transverse and oblique fibers of the extensor hood, and distal insertions that contribute to the extensor mechanism with oblique fibers (Fig 11).

At MR imaging, the lumbral muscles may be easily identified on axial sections. They are located at the palm, next to the deep flexor tendons from which they originate. The most dorsal interosseous muscles appear in the intermetacarpal spaces (Fig 16).
Proximal Phalanx and PIP Joint (Zones IV and III)

Distal to the MCP joint, the extrinsic and intrinsic tendons blend into the dorsal apparatus and are circumferentially distributed over the dorsum of the fingers (Fig 11). The extrinsic extensor tendon continues in the central and lateral bands (27) or slips (28). The central slip inserts on the base of the middle phalanx. The lateral slips merge with the intrinsic tendons, forming the conjoined tendons. The intrinsic tendons also provide medial fibers to form the central slip. Therefore, the extensor apparatus at the PIP joint consists of a unique crisscrossed fiber pattern that interconnects the central mechanism with the contribution of the intrinsic tendons (29). On axial MR images, the extensor apparatus at the dorsal zone of the proximal phalanx appears as a linear, low-signal-intensity structure circumferentially distributed over the dorsum (Fig 17). Frequent swelling of the fibers occurs at the middle dorsum and at both sides due to the combination of the different intrinsic and extrinsic elements of the extensor apparatus. Medium sagittal sections are very useful for visualizing the insertion of the central slip on the base of the middle phalanx (Fig 18).

Figure 17. Axial anatomic slice (a) and corresponding T1-weighted MR image (b) obtained at the proximal phalanx show a dorsal condensation of fibers (arrows), which corresponds to the extensor digitorum tendon, and lateral and medial fibers (arrowheads), which correspond to the intrinsic contribution to the extensor apparatus by the interosseous and lumbrical tendons.

Figure 18. (a, b) Sagittal T1-weighted MR image (a) and corresponding anatomic slice (b) obtained at the PIP joint show the insertion of the central slip (arrow) on the base of the middle phalanx. (c) Axial T1-weighted MR image obtained at the head of the proximal phalanx shows the relationship between the central slip (arrow) and the medial and lateral slips (arrowheads).
The tendons of the dorsal apparatus are also spatially and functionally connected by transverse and oblique retinacular ligaments (30). Transverse fibers are dorsally inserted into the conjoined tendons and palmarly inserted into the palmar plate of the PIP joint and into the C1 pulleys of the flexor sheath. Oblique fibers have their origin at the C2 pulley of the flexor sheath, with a position palmar to the PIP joint, and are dorsally inserted into the conjoined tendons at the dorsum of the DIP joint. Transverse fibers have been visualized with MR imaging (Fig 19). However, these fibers cannot be identified in macroscopic anatomic sections, probably because of the difficulty in differentiating them from neighboring structures. Oblique fibers are apparent only after anatomic dissection.

Middle Phalanx and DIP Joint (Zones II and I)

The conjoined tendons pass over the dorsal zone of the middle phalanx to converge distally and form the terminal tendon, which is then inserted on the dorsum of the base of the distal phalanx. The triangular ligament, which keeps these structures in a position dorsal to the middle phalanx, is located between the conjoined tendons (Fig 11).

These structures appear on both axial and sagittal MR images. Axial sections show the two conjoined tendons as low-signal-intensity structures in a dorsolateral position, at the middle phalanx. The triangular ligament appears as a fine, low-signal-intensity, linear structure located between the two conjoined tendons, in a position proximal to the formation of the terminal tendon (Fig 20). The point of insertion of the terminal tendon can be clearly viewed on medium sagittal sections (Fig 21).

Functional Anatomy
Digit extension is the result of simultaneous actions of both extrinsic and intrinsic muscles. Extension of the MCP joint is carried out mainly by the common extensor muscle and the appropriate extensor muscles by means of pulling the tendons over the sagittal bands (Fig 22). Besides limiting tendinous proximal excursion, the sagittal bands also prevent hyperextension of the MCP joint, which uses the remaining tendinous excursion to help extend the interphalangeal joints. The intrinsic muscles located under the rotation axis of the MCP joint help avoid this hyperextension by means of their flexor function. These muscles extend the interphalangeal joints with their distal
expansions. When the joint is extended, the oblique retinacular ligament, which has a volar origin at the transverse axis of the PIP joint, is tensed. This contributes to the extension of the joint owing to a tendonesis effect after the dorsal insertion into the DIP joint.

**Extensor Tendon Injuries**

Injuries to the extensor tendons of the fingers are common because of their poorly protected anatomic location. Clinical reports emphasize the importance of initial treatment and postoperative rehabilitation in achieving a good outcome (31). Because the excursion of the extensor tendons over the fingers is less than that of the flexors, preservation of their length is far more critical to restoring the normal tendon balance (32). The relationship between the location of injury and the outcome is an important concept. The type of injury, deformity, and surgical outcome will be different according to the affected anatomic regions. As a result, the categorical classification of tendon injuries into anatomic zones is crucial to the diagnostic process. As already mentioned, Verdan’s zone system is the most widely accepted (10).

Injuries at zone I (DIP joint) may provoke disruption of the terminal extensor tendon, which is dorsally and superficially located at this level (Fig 23). This type of lesion is called mallet finger and...
is characterized by a deficit of DIP joint extension (31). A mallet finger injury may be open, but the closed type is more frequent. The mechanism for the closed injury is most commonly sudden, forceful flexion of the DIP joint in an extended digit. This results in rupture of the terminal extensor tendon or avulsion of a bone fragment at its insertion. The most common treatment is closed splinting with the DIP joint in extension.

Zone II (middle phalanx) injuries are usually secondary to a laceration. At this level, the conjoined tendons are thin and oriented around the dorsal half of the phalanx. A simple laceration seldom transects all of the dorsal apparatus. If less than 50% of the tendon width is cut, the treatment involves routine wound care and splinting, followed by active motion. Injuries that involve more than 50% of the tendon width should be repaired primarily (33).

Zone III (PIP joint) injuries may cause disruption of the central slip with eventual development of a boutonnière deformity, secondary to flexion of the PIP joint and hyperextension of the DIP joint (34) (Fig 24). The injury can be closed or open, and the central slip may avulse with or without a bone fragment. Closed injuries may be caused by a blow to the dorsum of the PIP joint, acute forceful flexion of the PIP joint, or palmar dislocation of the PIP joint. The early injury may be associated with localized swelling and mild extensor lag but not deformity. The boutonnière deformity therefore develops gradually and may not be apparent during the first 7–14 days. Initial treatment should be splinting of the PIP joint in extension. Surgical indications are represented by a displaced avulsion fracture, associated instability of the PIP joint, and chronic symptomatic cases.

Zone IV (proximal phalanx) injuries are usually partial because at this level the dorsal apparatus is circumferentially distributed over the dorsum of the fingers and simple injuries seldom result in complete laceration. The lacerated tendon ends do not retract appreciably because of their interconnections and due to the presence of the retinacular ligaments. Partial lesions are treated by splinting the PIP joint in extension. For complete lacerations, surgical repair should be performed.

Zone V (MCP joint) injuries are almost always open and are commonly secondary to a human bite. The injury most often occurs with the joint in flexion, and the laceration in the extensor tendon may be proximal to the dermal injury. Primary tendon repair is indicated. Oblique lacerations may include the sagittal bands, and this may lead to subsequent subluxation or dislocation of the extensor tendon. Tearing of the sagittal bands and subsequent subluxation or dislocation of the extensor mechanism may also occur as a consequence of a closed injury secondary to a blow forcing the finger into flexion or after forced flexion and ulnar deviation of the digit (35) (Fig 25). In chronic untreated cases, the patient presents with a history of multiple episodes of pain and swelling over the MCP joint with a snapping

Figure 24. Complete rupture of the central slip secondary to a closed injury in a 28-year-old man. Sagittal T1-weighted (a) and axial T2-weighted (b) MR images show disruption of the central slip at its insertion on the base of the middle phalanx (arrow). A classic boutonnière deformity with flexion of the PIP joint and extension of the DIP joint is seen (arrowheads).
sensation in the fingers. Treatment of the sagittal band disruption is surgical repair in most cases.

At Zone VI (dorsum of the hand), the extensor tendons are very superficial. A relatively trivial-appearing skin laceration is often associated with one or more tendon lacerations. Single or partial lacerations in this zone may not result in loss of extension at the MCP joint because extensor forces are still transmitted from the adjacent extensor tendons through the intertendinous connections (19,20). Primary surgical repair is mandatory.

Deep lacerations are the usual cause of injury in zones VII and VIII (wrist and distal forearm) because the tendons at this level are relatively deeply located. The tendons at this level may retract quite proximal to the level of injury due to the elasticity in the musculotendinous units (33). Multiple tendons may be injured in this area, and in this situation restoration of independent wrist, finger, and thumb extension should be performed. Difficulties may also be encountered with injuries at the musculotendinous junction because the fibrous septa retract into the substance of the muscles.

As in other locations, MR imaging provides a clear depiction of tendinous disruptions, either complete or partial, and their precise locations. It is particularly useful in evaluation of extensor apparatus injuries, as the results of clinical examination are not always unequivocal, especially in the acute phase. Diagnosis of a partial tear with MR imaging is based on the presence of areas of increased signal intensity in a portion of the tendon on T1-weighted (and sometimes T2-weighted) images. A complete tendon tear appears as an area of discontinuity with fraying and irregularities at both ends of the ruptured tendon. In addition, evaluation of the rupture gap may prove useful, particularly in the proximal areas, where the frequency of retractions is higher, thus avoiding unnecessary surgical maneuvers. When the injury is acute, the tendon gap shows intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images. In the proximal areas, MR imaging also provides important information on the actual number of affected tendons in complex lesions. In lesions of the articular (odd) zones, it is crucially important to evaluate possible lesion extension to the supporting ligamentous structures and to the capsular articular ones, which represents an indication for surgical repair.

**Tenosynovitis**

Tenosynovial inflammation of any of the dorsal compartments of the wrist can occur. The most frequently affected is the first compartment (de Quervain tenosynovitis), followed with a substantially lower frequency by the sixth (extensor carpi ulnaris) and second (intersection syndrome) compartments (36).

De Quervain tenosynovitis is a common cause of dorsoradial wrist pain and implies an inflammation of the abductor pollicis longus and extensor pollicis brevis tendons. Any thickening of the
tendons due to an acute or repetitive trauma restrains gliding of the tendons through the sheath. Efforts at thumb motion cause pain and perpetuate the inflammation and swelling. Increased thickness of the abductor pollicis longus and extensor pollicis brevis tendons and the presence of peritendinous fluid within the synovial sheath are the most reliable findings at MR imaging (37) (Fig 26).

Intersection syndrome is the result of inflammation of the tenosynovium of the radial wrist extensors (extensor carpi radialis longus and extensor carpi radialis brevis) where they cross under the more obliquely oriented abductor pollicis longus and extensor pollicis brevis tendons (38). This condition is much less common than de Quervain tenosynovitis, the syndrome with which it is most easily confused. It can be caused by direct trauma to the second extensor compartment or by repetitive wrist flexion and extension. MR imaging demonstrates primary involvement of the second dorsal compartment, showing hyperintense fluid surrounding the tendons on T2-weighted images (Fig 27).

Chronic dorsoulnar wrist pain can be due to tenosynovitis of the sixth dorsal compartment. A predisposing cause may be recurrent subluxation of the extensor carpi ulnaris tendon due to a tear of the ulnar side of the compartment (38). MR imaging permits diagnosis of the tenosynovitis and evaluation of the tendon location.

Conclusions
Owing to use of surface coils and to spatial and tissue differentiation capability, MR imaging allows excellent identification and depiction of most tendinous and retinacular structures of the extensor apparatus of the fingers. In the different extensor zones, MR imaging findings are similar to those obtained with macroscopic anatomic sectioning. Some specific distal retinacular structures, as well as the tendinous multiplicity and interconnections at the dorsum of the hand, are difficult to identify. Therefore, they represent a diagnostic difficulty for both MR imaging and anatomic sectional assessment. These structures can be demonstrated only with dissection techniques.

Radiologists must become familiar with this anatomy. Knowledge of it is crucial for better comprehension of the lesions, better assessment of the pathologic conditions with MR imaging, and optimization of this technique as a diagnostic tool for this frequently injured part of the body.

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References


