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Sonography of the finger flexor and extensor system at the hand and wrist level: findings in volunteers and anatomical correlation in cadavers

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Abstract We present a review of sonography of the flexor and extensor system of the hand and wrist in volunteers and cadavers. CT tenography also was performed in cadaveric specimens. Anatomical structures of the extensor system that were assessed with sonography included the extensor tendons and insertions, retinaculum, and dorsal hood. On the flexor side, the variable relationship between the flexor superficialis and profundus could be appreciated. Volar plates, tendon insertions, and annular pulleys could also be investigated. Sonography can show details of the finger flexor and extensor system.

Keywords Finger · Hand · Wrist · Sonography · Anatomy

Introduction

Sonography can assess delicate musculoskeletal structures. The excellent spatial resolution of sonography allows it to be used in the assessment of fine hand structures. In this article, we review the clinically relevant anatomy of the flexor and extensor complex in the hand and fingers. Accurate diagnosis and adequate treatment of injuries of these structures is essential, given the importance of normal hand function in both professional and everyday activity. An understanding of normal anatomy, as depicted on sonograms, is essential for adequate diagnosis of injuries. Our review is based on sonographic images obtained in volunteers and cadavers.

Technical considerations

Nine volunteers aged 22–42 years (mean, 30 years) were studied with sonography. An ATL HDI 5500 system (Philips) with a 12-MHz transducer, and an Aloka Alpha 10 system with a 13-MHz transducer (Aloka, Tokyo, Japan) were used to study volunteers and cadaveric specimens. Compound imaging and zoom functions were used liberally. Ultrasound transmission gel was used liberally instead of a gelpad. In volunteers, dynamic scanning was used to better visualize anatomical structures. Six cadaveric specimens were obtained from the department of anatomy; three were embalmed, and three were fresh specimens. In one cadaver hand, the synovial sheath

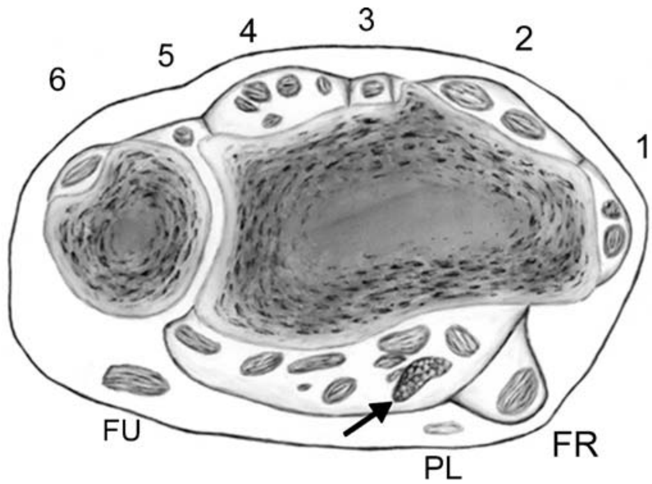


Fig. 1 Line drawing of transverse section of wrist. At the ventrolateral aspect, the extensor pollicis brevis and abductor pollicis longus tendons are seen in the first compartment (*1*). More laterally, the extensor carpi radialis brevis and longus tendons are noted in the second compartment (*2*). The extensor pollicis longus tendon is located adjacent to Lister's tubercle in the third compartment (*3*). The common extensor group makes up the fourth compartment (*4*). The extensor of the small finger is located in the same sagittal plane as the distal radioulnar joint space in the fifth compartment (*5*). The extensor carpi ulnaris tendon is seen in a sulcus in the distal ulna in the sixth compartment (*6*). In a superficial location at the ventral aspect, the flexor carpi radialis (*FR*), flexor carpi ulnaris (*FU*), and palmaris longus are seen (*PL*). Note position of palmaris longus superficial to the median nerve (*arrow*) in the carpal tunnel

of the second to fourth fingers and the synovial sheath at the wrist were injected with iodinated contrast medium (Hexabrix, Guerbet, France) under fluoroscopic guidance. CT was performed on a Somatom Plus clinical system (Siemens, Erlangen, Germany). CT images were used for anatomical correlation. After imaging was completed, three specimens were deep frozen and sliced (coronal, sagittal, transverse planes) using a band saw. The other specimens were dissected. Dissections of the embalmed specimens and selected slices of the fresh specimens were photographed for correlation.

Anatomical considerations

Wrist

At the dorsal aspect of the wrist, the tendons are located in six different extensor compartments shown in Figs. 1, 2

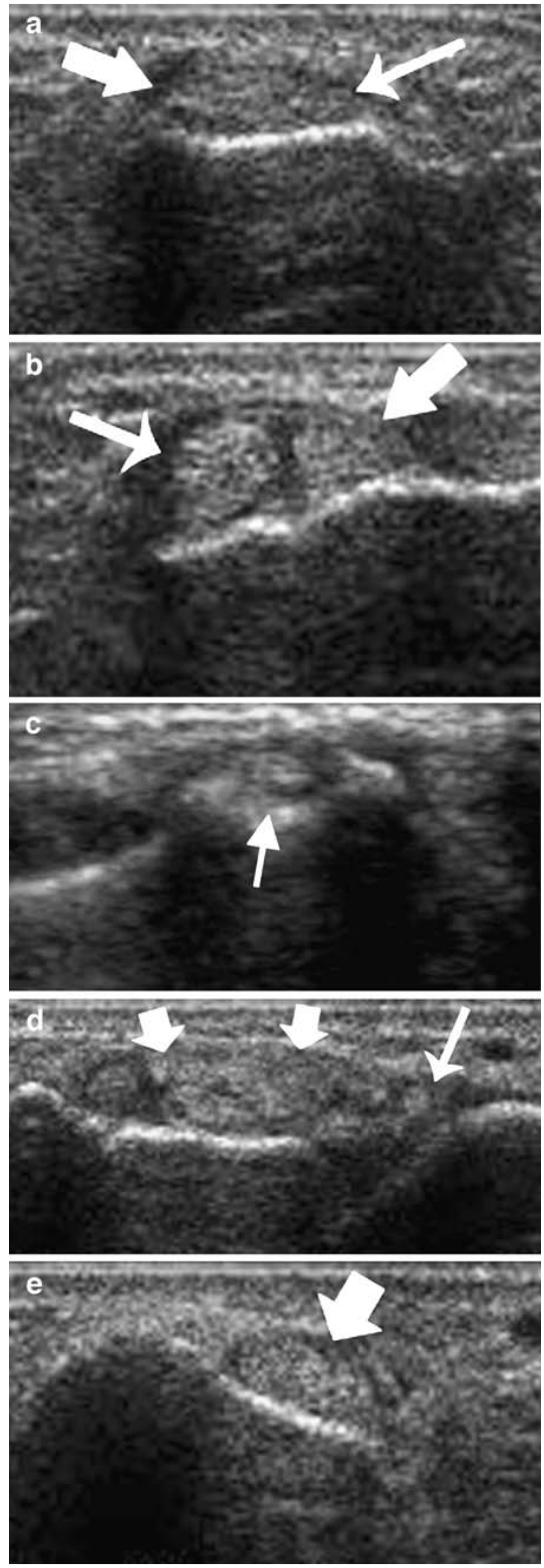


Fig. 2 Transverse sonograms of extensor tendons at wrist. **a** First compartment. Smallest tendon corresponds to the extensor pollicis brevis (*thin arrow*). Larger tendon is the abductor pollicis longus (*thick arrow*). **b** Second compartment. Extensor carpi radialis brevis and longus (*arrows*) tendons are shown. **c** Third compartment. Extensor pollicis longus is seen in sulcus at Lister's tubercle (*arrow*). **d** Fourth and fifth compartment. Extensor tendon for small finger (*thin arrow*) and extensor group (*thick arrows*) are shown. **e** Sixth compartment. Extensor carpi ulnaris is shown (*thick arrow*)

[1, 2]. On sonography, the tendons exhibit a characteristic fibrillar pattern along their longitudinal axis. Along the transverse axis, hyperechoic punctuations are seen interspersed with hypoechoic areas. Anisotropy artefact, however, may render the tendon hypoechoic. Peritendinous structures are seen as a thin hypoechoic band of tissue. Each compartment is covered by a retinaculum. The retinacula of the extensor compartments can often be seen as hypoechoic band-like structures covering the tendons [3].

The thumb has two extensor tendons [4]. The extensor pollicis longus tendon is located on top or on the ulnar side of Lister's tubercle. It then crosses over the extensor carpi radialis tendons and moves obliquely towards the base of the thumb. The extensor pollicis brevis tendon is located more radially at the level of the wrist. It makes up the first extensor compartment, together with the abductor pollicis longus tendon. The extensor pollicis brevis tendon usually inserts on the base of the proximal phalanx, although it may continue to insert on the base of the distal phalanx. Both tendons are well seen on sonography.

At the wrist, the extensor tendons for each compartment have synovial sheaths, which are normally not seen at sonography. More distally, at the level of the mid-hand and the metacarpaphalangeal area, the extensor tendons no longer possess synovial sheaths.

At the ventral aspect of the wrist, three tendons have a more superficial location (Figs. 1 and 3). The flexor carpi radialis passes laterally to the flexor retinaculum in a separate compartment. It inserts on the carpal bones and on the base of the second and third metacarpal bones. On the ulnar aspect, the flexor carpi ulnaris tendon inserts on the pisiform bone. At sonography, both tendons have a typical fibrillar pattern. Depending on the angle of incidence of the ultrasound beam, anisotropy artefacts may be more or less pronounced. The palmaris longus tendon lies superficial to the median nerve and flexor retinaculum and is invariably present. The palmaris longus tendon typically inserts on the palmar fascia. The tendon can be depicted at sonography as

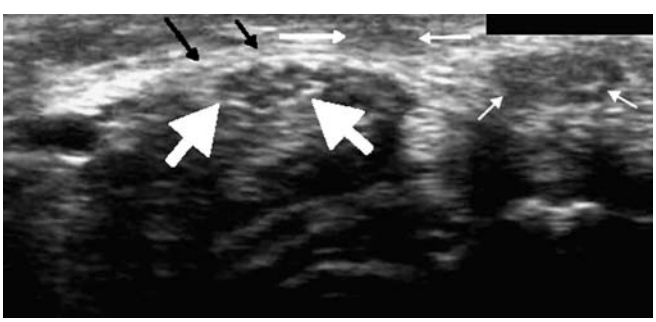


Fig. 3 Tranverse sonogram at carpal tunnel. Palmaris longus (*thin long white arrows*) is seen in superficial location. Median nerve (*thick white arrow*) is seen deep to the flexor retinaculum (*thin black arrows*). Also note the flexor carpi radialis (*thin white arrow*)

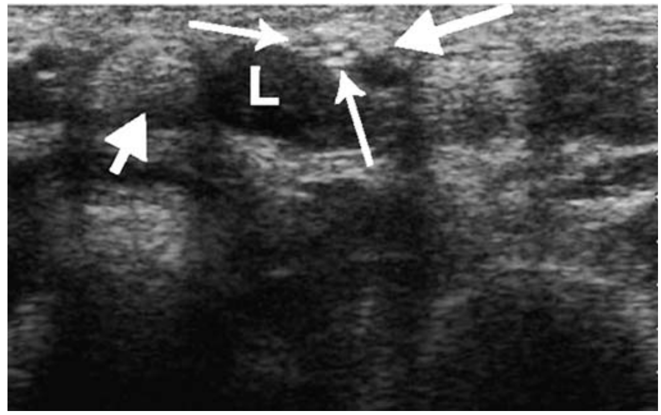


Fig. 4 Transverse sonogram of midhand in cadaver. Flexor tendons are shown (*short arrow*). Lumbricalis muscle is shown on radial side of flexor tendons (*L*). Note nerve structures (*long arrow*)

a hyperechoic anisotropic structure superficial in location to the more hypoechoic median nerve.

Slightly deeper, the flexor tendon group is seen to enter the carpal tunnel, deep to the flexor retinaculum [5, 6]. The flexor superficialis tendons are seen in proximity to the flexor retinaculum. The flexor profundus tendons are visualized at a deeper level accompanied by the flexor pollicis longus tendon. The retinaculum and tendons are clearly visualized on sonography. Inside the carpal tunnel, the median nerve is seen in a superficial position (Fig. 3).

Midhand

An important sonographic landmark seen deep to the flexor tendons and lumbricalis muscle is the insertion of the

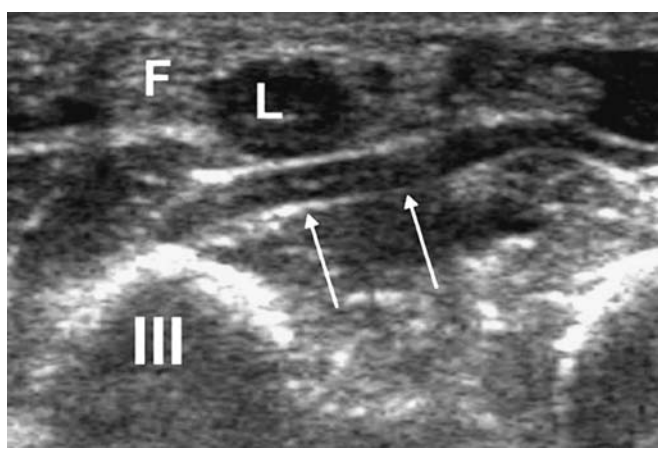


Fig. 5 Transverse sonogram of midhand in cadaver (third metacarpal bone). Characteristic insertion of the adductor pollicis muscle (*arrows*) on the third metacarpal (*III*) is shown. This insertion is an excellent landmark. Flexor tendon (*F*) and lumbricalis muscle (*L*) are also seen

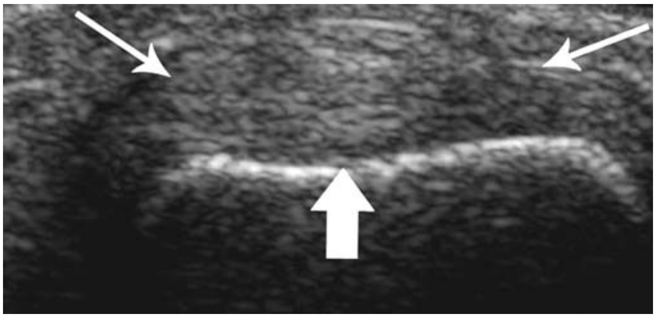


Fig. 6 Transverse sonogram of dorsal hood. At the dorsal hood level, the central tendon is shown (*bold arrow*) and sagittal bands on both sides (*thin arrows*)

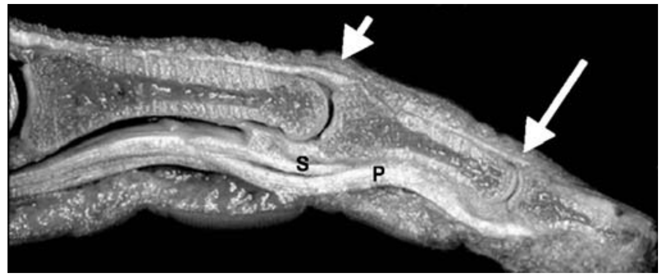


Fig. 8 Photograph of sagittal slice in fresh specimen. Dorsally central slip (*short arrow*) extensor insertion and distal slip insertion (*long arrow*) are shown. Ventrally flexor superficialis (*s*) and profundus (*p*) are seen

adductor pollicis longus tendon on the third metacarpal (Fig. 5), a thick tendon that is easily recognizable.

At the midhand, the flexor tendons have a characteristic topographical organization. The flexor superficialis tendons are located more ventrally [7, 8]. At the radial side of the tendons, the muscular belly of the lumbricalis muscle can be observed. The lumbricalis muscle has a slightly more hypoechoic appearance at ultrasound compared to the flexor tendons (Fig. 4).

The insertional anatomy of the lumbricalis muscles is complex and beyond the purpose of this article. Superficial to the lumbricalis muscle, the neurovascular bundle is evident. At this level, the arteries are designated common palmar arteries. Digital nerve branches consist of divisions of the median and ulnar nerve.

Longitudinal splits in the extensor tendons, representing normal anatomic variations, are commonly present. The second digit, for example, usually has two tendons, one termed the extensor tendon of the second digit, and the other the extensor indicis proprius tendon.

Metacarpophalangeal joint

At the metacarpophalangeal joint, the deepest tissue layer corresponds to the joint capsule, but contains reinforcements such as the collateral ligaments [9–12]. The superficial layer is made up of the extensor tendons mixed with the interosseous tendons. This superficial layer also contains the dorsal hood structures (Fig. 6). The extensor tendon is centrally located and has a slightly hyperechoic aspect on sonography. At both sides of the tendon, slightly hyperechoic triangular areas corresponding to these attachments can be seen. Functionally, it is essential that such bands are present. If not, with ulnar or radial deviation of the hand, the tendons would be displaced from their central position at the metacarpal heads.

Ventrally, the deeper layer is in continuity with the volar plate. The flexor tendons are located superficial to the volar plate and covered by the synovial sheath and the A1 pulleys. The transverse palmar ligament connects the volar plate areas of the different digits. Sonography can depict the A1 pulleys as slightly hypoechoic bandlike structures covering the tendons.

Finger

On the dorsal aspect, the extensor tendon divides in three separate portions after passing the metacarpaphalangeal joint (Figs. 7, 8) [9]. One portion is situated on top of the proximal phalanx. Two bundles separate from the main tendon and course along both sides of the finger. The

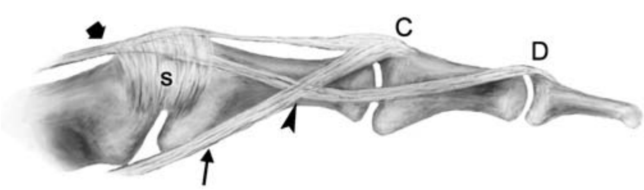


Fig. 7 Line drawing of lateral aspect of metacarpophalangeal area and finger. Extensor tendon is shown at the metacarpophalangeal joint (*black short arrow*). In this region, the tendon is kept centered over the metacarpal head by sagittal bands (*S*). The interosseus tendon (*long arrow*) courses from ventrally to dorsally. At the lateral aspect of the proximal phalanx, intermingling (*arrowhead*) of the interosseus and extensor tendons is seen. Central slip (*C*) and distal slip (*D*) insertion are seen

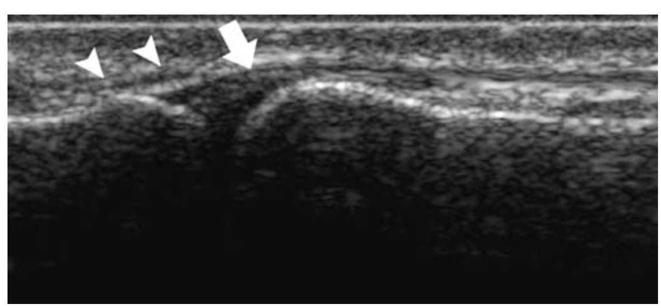


Fig. 9 Sagittal sonogram of central extensor insertion. Insertion of central slip (*arrow*) is seen. Fibers continue distally (*arrowheads*) to form distal insertion (not shown)

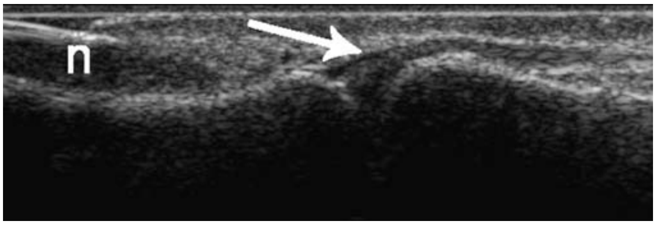


Fig. 10 Sagittal sonogram of distal extensor insertion. Distal insertion is seen (*arrow*). Also note nailbed (*n*)

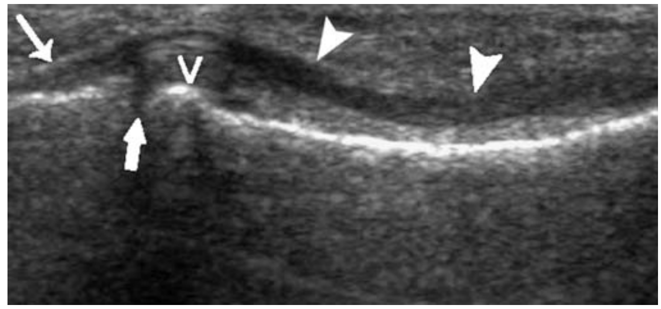


Fig. 12 Sagittal sonogram of the flexor profundus. Insertion (*thin arrow*) of the flexor profundus (*arrowheads*) is seen. Note distal interphalangeal joint space (*thick white arrow*) and associated volar plate (*v*)

tendons from the interosseous muscles and the tendons from the lumbricalis muscle course from ventrally to dorsally along the sides of the proximal phalanx. These tendons also divide into two portions, one that contributes to the central extensor insertion, and one that contributes to the distal extensor insertion [9].

More distally, at the base of the middle phalanx there is a first attachment of the extensor system onto the bone, which is designated the central insertion (Fig. 9). An advantage of sonography compared to other modalities is that it is possible to perform a dynamic study to assess tendon continuity. The typical avulsive injury at this site is termed central slip avulsion. This injury may lead to a boutonnière deformity [13]. The interosseous tendons, together with the lateral portions of the extensor tendon, continue to insert on the base of the distal phalanx, and form the distal insertion, also termed distal slip (Fig. 10). The typical lesion of the distal slip is termed mallet finger, and usually diagnosis of this injury is clinically evident. The distal insertion is also easily recognized on sonography.

Ventrally, the relationship of the flexor superficialis and profundus tendons varies considerably throughout the finger (Figs. 11, 12, 13, 14). On sonography, at the level of the metacarpophalangeal joint, both tendons are well visualized and the flexor superficialis tendon is located more ventrally. Slightly more distally, the flexor superficialis tendon obtains a semilunar aspect, before dividing into a medial and a lateral portion. The flexor profundus tendon then passes through this opening in the flexor superficialis tendon and continues distally to insert onto the base of the distal phalanx. The flexor superficialis tendon inserts at the level of the middle aspect of the middle phalanx. Its insertion then extends on both sides of the flexor profundus tendon. At the site of attachment, small bony ridges on the ventromedial and ventrolateral aspect of the middle phalanx may be seen.

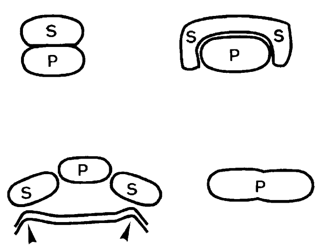


Fig. 11 Line drawing of transverse sections through finger. Changing appearance is noted at different levels (from proximal to distal). At midhand, the flexor superficialis (*S*) tendon lies superficial to the flexor profundus (*P*) tendon. At the proximal phalanx, the flexor superficialis tendon opens up to allow passage of the flexor profundus tendon. At the middle phalanx, the flexor superficialis tendon splits into two portions and inserts on a small protrusion of a bone (*arrowheads*). At the distal aspect of the middle phalanx, the flexor profundus continues to insert on the base of the distal phalanx

The flexor tendons are located in a synovial sheath that extends from the metacarpophalangeal joint area to the distal phalanx. There is no communication between this sheath and the joint spaces. In addition to this synovial sheath, the tendon is covered by two types of fibrous reinforcements, termed the annular and cruciform pulleys [14–16]. The cruciform reinforcements are less important and are difficult to recognize on anatomic dissection. By contrast, the annular reinforcements are strong bands easily recognizable at dissection. They are classified as five different bands, termed the A1 through A5 pulleys (Figs. 15, 16). The cruciform pulleys are classified as C1–C3. In our experience, ultrasound allows depiction of all pulleys. The pulleys can be identified as thin hypoechoic bands adjacent to the tendons. Gently flexing and extending the fingers during sonography can help to identify the position of the annular pulleys.

Usually, when an injury occurs, it involves the A1 pulley first, and then continues distally. The purpose of the

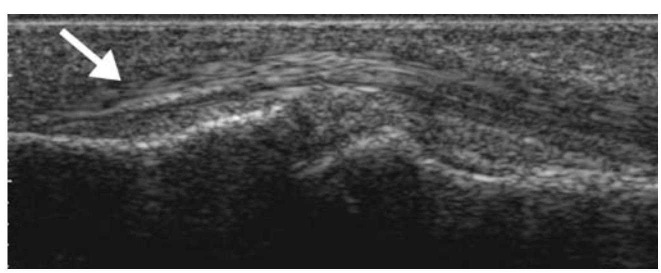
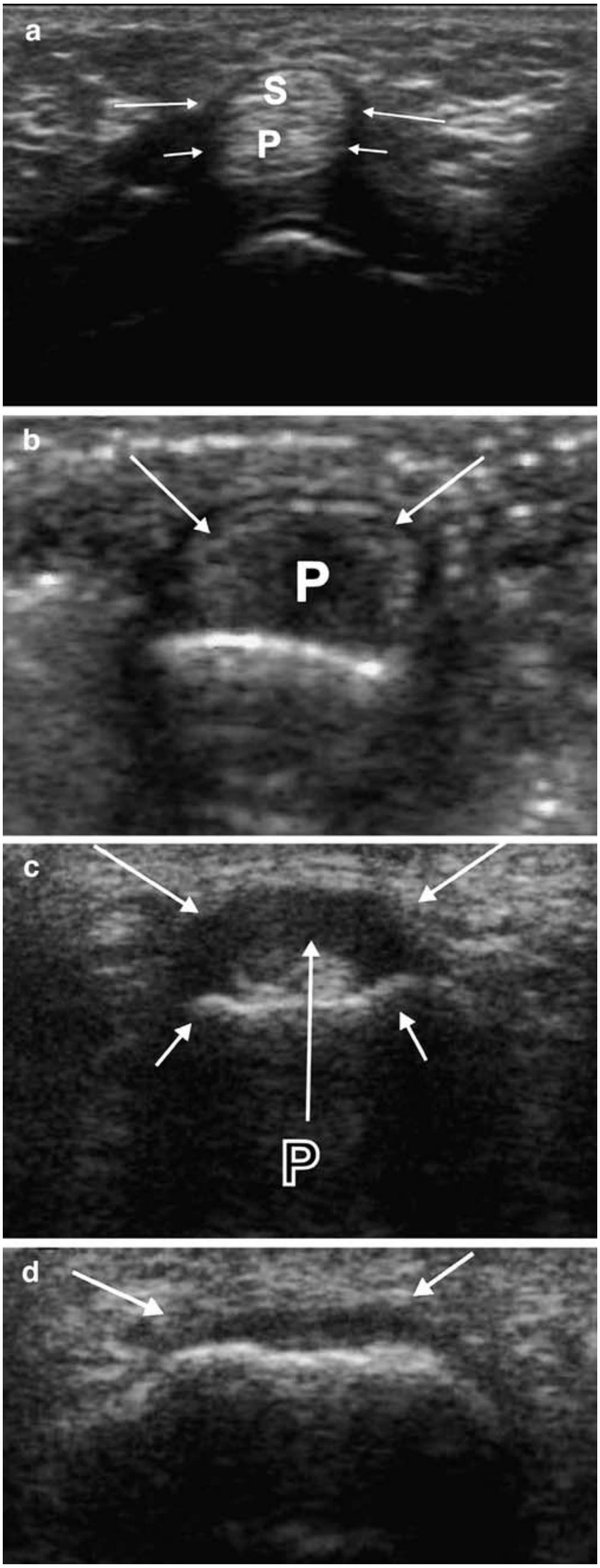


Fig. 13 Sagittal sonogram of the flexor superficialis. Insertion of the flexor superficialis at the middle phalanx is seen (*arrow*)



◀ **Fig. 14** Transverse sonogram in 30-year-old volunteer. In **a**, the flexor superficialis (*S*, *long arrows*) is seen superficial to the flexor profundus (*P*, *short arrows*). In **b**, the flexor superficialis has a U shape and allows for passage of the flexor profundus (*P*). This region exhibits a "buttonhole" appearance on ultrasound due to different fiber orientations relative to incidence of ultrasound beam. In **c**, insertion of the flexor superficialis onto two small bony protrusions at the ventral aspect of the middle phalanx is shown (*short arrows*). Note the centrally located flexor profundus (*P*, *long arrows*). In **d**, the flexor profundus (*arrows*) continues and inserts on the base of the distal phalanx

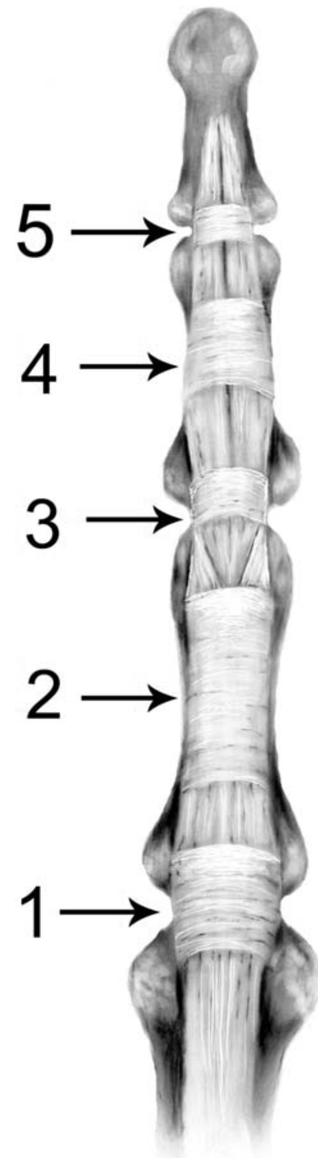


Fig. 15 Line drawing of digital annular pulleys. A1 (*1*) through A5 (*5*) pulleys are shown

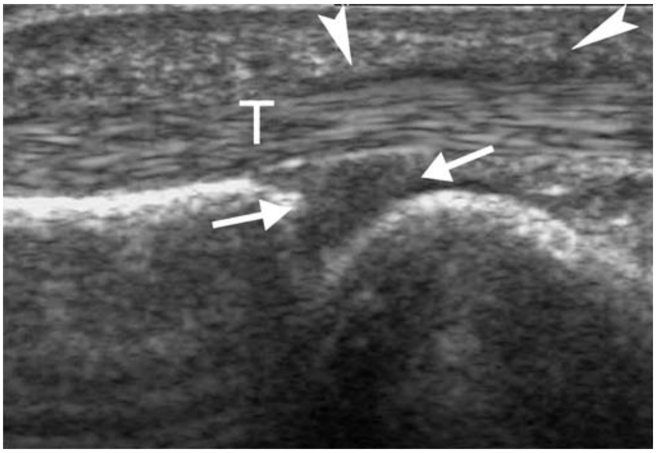


Fig. 16 Sonogram of pulley and volar plate. Sagittal sonogram shows the volar plate at the level of joint space (*arrows*), with the flexor tendon more superficial (*T*). Also note the hypoechoic pulley (*arrowheads*)

annular pulleys is to keep the tendon in close contact with the bone during flexion of the finger. Indeed, when these pulleys are torn, the result is a bowstring appearance, with the flexor tendon at an increased distance from the bone [16]. At the level of the joints, the flexor tendons are at a slight distance from the bone. This is related to the shape of the head of a phalanx, but also to the presence of thick volar plates at the level of the interphalangeal and metacarpophalangeal joints (Fig. 16). The volar plates are fibrous structures attached to the distal phalanx and joint capsule

Fig. 17 CT tenography in cadaveric hand. The tendon sheath of the third finger and wrist were injected with iodinated contrast medium. Note the lobulated appearance of the tendon sheath (*thin arrow*). Also note termination of the sheath of the finger at midhand (*short thick arrow*) and termination of the sheath at wrist (*long thick arrow*)

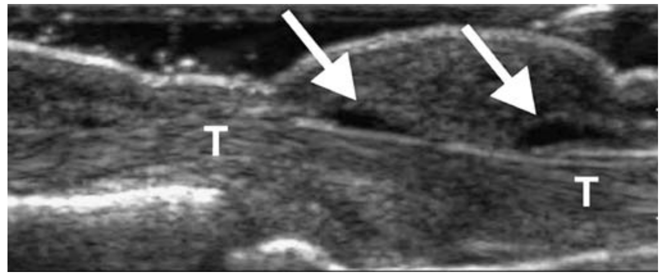


Fig. 18 Sonogram of cadaveric finger following tenography. Note the lobulated appearance of the sheath (*arrows*) adjacent to the flexor tendons (*T*)

that extend proximally [17]. The oblique bands of the collateral ligaments of the joint connect to the volar plates. Hence, volar plate injuries may be associated with injuries of the collateral ligaments.

The synovial sheath of the second to fourth digits extends from the fingertips to an area proximal to the metacarpophalangeal joint (Figs. 17, 18). It is in this latter area that changes may be seen in the setting of the trigger finger. Although the synovial sheaths on the palmar side of the hand may show considerable anatomic variation, the most characteristic configuration consists of a separate sheath for the second to fourth fingers. The thumb also has a separate sheath that extends into the wrist area. A sheath is also present at the level of the wrist and usually communicates with the sheath of the fifth finger. In some individuals, a communication between the sheath of the thumb, wrist, and the fifth finger is present.

Our observations during CT tenography demonstrate that the normal synovial sheath has an undulating aspect over its entire length. Hence, synovial fluid may be more pronounced in some areas than in others. Our sonographic observations in cadavers with injected sheaths confirm this undulating appearance of the tendon sheath. Hence, a moderate effusion in the synovial sheath may erroneously be taken as evidence of tiny peritendinous cysts.

In summary, we described the anatomy of the finger flexor and extensor system from the wrist region to the fingertips, with emphasis on structures that are clinically important. In light of the improved resolution now available with sonography, it is all the more crucial that practitioners have an excellent understanding of normal sonographic anatomy for correct diagnosis of injuries of these structures.

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References

1. Lee JC, Healy JC (2005) Normal sonographic anatomy of the wrist and hand. Radiographics 25:1577–1590
2. Bianchi S, Martinoli C, Abdelwahab IF (1999) High frequency ultrasound examination of the wrist and hand. Skeletal Radiol 28:121–129
3. Taleisnik J, Gelberman RH, Miller BW, Szabo RM (1984) The extensor retinaculum of the wrist. J Hand Surg 9:495–501
4. De Maeseneer M, Marcelis S, Osteaux M, Jager T, Machiels F, Van Roy P (2005) Sonography of a rupture of the tendon of the extensor pollicis longus muscle: initial clinical experience and correlation with findings at cadaveric dissection. AJR Am J Roentgenol 184 (1):175–179
5. De Maeseneer M, Van Roy P, Jacobson JA, Jamadar DA (2005) Normal MR imaging findings of the midhand and fingers with anatomic correlation. Eur J Radiol 56(3):278–285
6. Wilson D (2004) Ultrasound assessment of carpal tunnel syndrome. Clin Radiol 59(10):909
7. Rubin DA, Kneeland JB, Kitay GS, Naranja RJ Jr (1996) Flexor tendon tears in the hand: use of MR imaging to diagnose degree of injury in a cadaver model. AJR 166:615–620
8. Drapé JL, Tardif-Chastenet de Gery S, Silbermann-Hoffman O, Chevrot A, Houvet P, Alnot, JY, Benacerraf R (1998) Closed ruptures of the flexor digitorum tendons: MRI evaluation. Skeletal Radiol 27:617–624
9. Landsmeer JM (1972) Cross-section analysis of the human finger. J Anat 111:474–475
10. Theumann NH, Pfirrmann CW, Drape JL, Trudell DJ, Resnick D (2002) MR imaging of the metacarpophalangeal joints of the fingers: part I. Conventional MR imaging and MR arthrographic findings in cadavers. Radiology 222(2):437–445
11. Landsmeer JMF (1949) The anatomy of the dorsal aponeurosis of the human finger and the functional significance. Anat Rec 104:31–44
12. Clavero JA, Golano P, Farinas O, Alomar X, Monill JM, Esplugas M (2003) Extensor mechanism of the Fingers: MR-anatomic correlation. RadioGraphics 23:593–611
13. Massengill JB (1992) The boutonnière deformity. Hand Clin 8:787–801
14. Martinoli C, Bianchi S, Nebiolo M, Derchi LE, Garcia JF (2000) Sonographic evaluation of digital annular pulley tears. Skeletal Radiol 29:387–391
15. Boutry N, Titecat M, Demondion X, Glaude E, Fontaine C, Cotton A (2005) High frequency ultrasonographic examination of the pulley system. J Ultrasound Med 24:133–139
16. Parellada JA, Balkisson ARA, Hayes CW, Conway WF (1996) Bowstring injury of the flexor tendon pulley system: MR imaging. AJR 167:347–349
17. Nance EP Jr, Kaye JJ, Milek MA (1979) Volar plate fractures. Radiology 133:61–64