Key aspects of anatomy, surgical approaches and clinical examination of the hand

Ashley W Newton

Xenia N Tonge

David H Hawkes

Vijay Bhalaik

Abstract

Knowledge of the functional anatomy of the hand is essential to be able to successfully clinically examine and operate on it. The topic of hand anatomy, clinical examination and surgical approaches is therefore closely linked and discussed in this article. The focus will be on detailed functional anatomy of the joints, tendons, and other soft tissue structures of the hand, related to the clinical examination and surgical approaches. Particular attention will be paid to the superficial and deep flexor tendons and how to examine them; the extensor mechanism and examination of the central slip; and surgical approaches to the finger. The pathoanatomy of Dupuytren's disease and fingertip infections are also discussed.

Keywords anatomy; approaches; clinical assessment; examination; extensor tendon; flexor tendon; hand

Introduction

The complex anatomy of the hand is responsible for a diverse range of functions. These range from fine motor movements, such as those needed for writing, to a strong powerful grip. A simple injury can easily disrupt the delicate balance, leading to catastrophic functional consequences. Thus, a sound knowledge of these anatomical structures and how to clinically assess them is needed to appropriately treat pathologies of the hand. The function of the hand and wrist is closely interconnected. A detailed discussion of clinical assessment of the wrist was recently published in this journal,[1] and there is often considerable overlap between clinical assessment of the hand and wrist. This paper will focus on the digits.

***Ashley W Newton** MBChB MRes MRCS PGCTLCP FHEA Specialty Registrar in Trauma and Orthopaedic Surgery, Health Education North West (Mersey) Deanery, Liverpool, UK. Conflicts of interest: none declared.*

***Xenia N Tonge** BSc(Hons) MSc BMBS Core Surgical Trainee, Health Education North West (Mersey) Deanery, Liverpool, UK. Conflicts of interest: none declared.*

***David H Hawkes** MBChB MPhil MRCS Specialty Registrar in Trauma and Orthopaedic Surgery, Health Education North West (Mersey) Deanery, Liverpool, UK. Conflicts of interest: none declared.*

***Vijay Bhalaik** MBBS MRCS FRCS Consultant Hand and Upper Limb Surgeon, Wirral University Teaching Hospitals NHS Foundation Trust, UK. Conflicts of interest: none declared.*

Joints

The five metacarpal bones articulate proximally with the distal row of carpals and each other (except for the thumb) and the proximal phalanges distally. The thumb lies in a different anatomical plane to the fingers; it is rotated 90° along its longitudinal axis. For example, the radial side of the thumb lies in the same plane as the volar surface of the fingers, the volar surface of the thumb sits in a plane with the ulnar side of the fingers and so on.

The thumb also has a significantly increased range of movement compared to the digits. To allow for this, the thumb metacarpal only articulates with the trapezium proximally, in a saddle configuration. Each digit has a proximal, middle and distal phalanx; the thumb only has a proximal and distal phalanx.

The volar plate is a dense fibrocartilaginous structure, situated volar to the joint capsule and helps to prevent hyperextension of the joints. There are three volar plates in each of the digits and two in the thumb which form the volar aspect of the joint capsule.

The metacarpophalangeal joint

The metacarpophalangeal joints (MCPJs) are synovial, ellipsoid joints and allow flexion, extension, abduction, adduction and circumduction of the digits. The articular surface of the metacarpal head is rounded and the associated articular surface of the proximal phalanx has a shallow concavity which leads to a multiaxial condyloid joint. These mobile joints are stabilized by collateral ligaments, the volar plate, joint capsule, intrinsic and extrinsic tendons.

The MCPJ volar plate is attached to the head of the metacarpals through vertical fibres from the accessory collateral ligaments, transverse intermetacarpal ligaments and oblique fibres extending to the interosseous fascia. The distal attachment of the plate is to the volar aspect of the base of the proximal phalanx. The MCPJ ligament configuration is shown in Figure 1.

The ulnar collateral ligament traverses the MCPJ obliquely from a dorsal to volar direction, to insert on proximally on the volar aspect of the proximal phalanx. On the radial side the radial collateral ligament originates on the dorsal surface of the metacarpal head and inserts on the lateral tubercle of the proximal phalanx. There are also accessory collateral ligaments, which are orientated in a more vertical direction. They span between the volar plate and proper collateral ligaments, acting to stabilize the volar plate.

The interphalangeal joints

The proximal interphalangeal joint (PIPJ) and distal interphalangeal joint (DIPJ) are synovial hinge joints and only allow flexion and extension of the digits. The osseous structure of the PIPJ and DIPJ confers more stability than that of the MCPJ. The proximal articular surfaces of the phalanges consist of two condyles, which corresponds to two concaved articular facets on the distal surfaces.

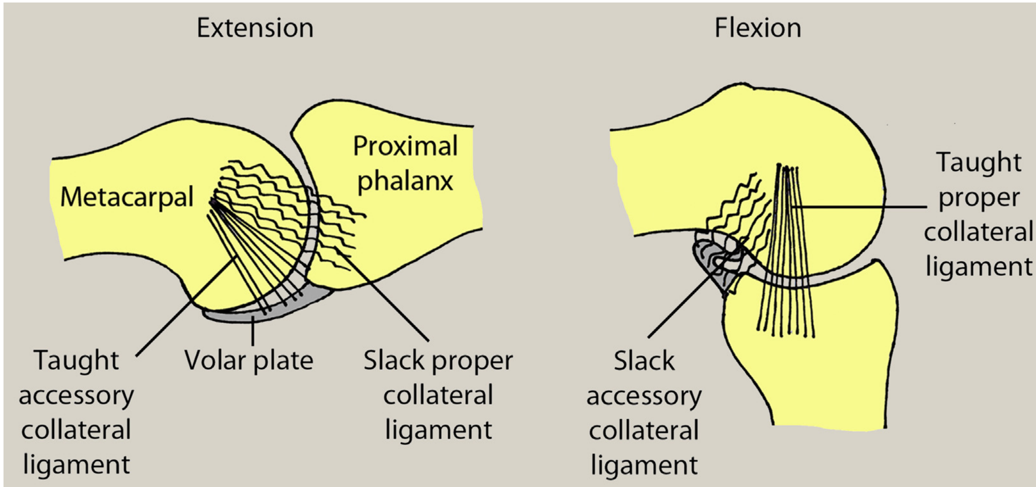

Figure 1 Diagrammatic representation of metacarpophalangeal joint showing the relationship between proper collateral ligament (PCL) and accessory collateral ligament (ACL). In flexion the PCL is taught and the ACL lax. The opposite is found with the joint in extension.

The PIPJ volar plate has a slightly different arrangement in that, proximally, the plate extends in to two fork-like appendages known as check-rein ligaments. These are continuous with the periosteum of the proximal phalanx.[2] The space between the ligaments allows for passage of the digital vessels under the flexor sheath and the vincular arteries to reach the tendons. Distally, the corners of the volar plate are anchored to the base of the middle phalanx via Sharpey's fibres at the points where the accessory collateral ligaments also insert.[3]

Muscles

Muscles acting on the hand and digits can be divided into intrinsic muscles and extrinsic muscles. A summary of origins and insertions along with the nerve supply to these muscles can be found in Table 1 (extrinsic muscles) and Table 2 (intrinsic muscles).

Flexor tendons

Anatomy

Origins, insertions and nerve supply of the flexor tendons are detailed in Table 1. The tendons of flexor digitorum superficialis (FDS) have a unique configuration. As the tendons cross the metacarpophalangeal joint, they become concave and a shallow groove develops on the volar surface. The tendons then completely divide in two at the level of the proximal phalanx. These divisions wrap around the central flexor digitorum profundus (FDP) tendon, and rotate on their longitudinal axis to insert on each side of the volar surface of the middle phalanx. Following the division, some fibres from each strand cross over beneath the FDP tendon to join with the opposite side, creating what is known as Camper's chiasm. FDS and FDP blood supply is via vincula (Figure 2).

Flexor sheath and flexor pulleys

The flexor tendon sheath is a soft tissue structure that surrounds the flexor tendons and is formed from two distinct components. Firstly, there is the membranous part, the sealed synovial tissue tube, that the tendons pass through. This sheath is a double-walled tube, comprising of visceral and parietal layers. It contains synovial fluid that ensures smooth gliding of the tendons during flexion and extension.

Secondly, the retinacular tissue forms the pulley system. The retinacular portions of the sheath are fibrous tissue bands that wrap over the membranous sheath, anchoring the sheath to the volar aspect of the digits and preventing bow-stringing during flexion. This allows the efficient conversion of translational force created by the muscle, to a rotational movement of the fingers.[4] Without the pulley system a much larger tendon excursion would be required to generate the same degree of flexion. The pulley system is shown in Figure 3.

Flexor pulleys of the thumb

The flexor apparatus of the thumb comprises of the long flexor, FPL and the thenar muscles. The pulley system in the thumb has a different configuration to that of the digits owing to the reduced number of phalanges and the presence and position of the thenar muscle, adductor pollicis. There are two or three annular pulleys (anatomical variation exists). The A1 pulley extends over the tendon from the MCPJ to the proximal phalanx. The oblique pulley spirals from the ulnar surface of the proximal phalanx at the junction between the phalanx and the adductor pollicis tendon. It crosses the interphalangeal joint (IPJ) and inserts onto the base of the radial side of the distal phalanx. The Av pulley, not always present, lies between the A1 and oblique pulley. Finally, the A2 is found proximal to the insertion of the flexor pollicis longus (FPL) tendon, overlying the IPJ and inserting onto the volar plate.[5]

Zones of injury

The flexor tendons are divided into five zones for the purposes of describing the level of an injury, as shown in Figure 4.

Examination of flexor tendons

It is best to examine the hand by sitting directly opposite the patient. There should be a hand examination table in between as shown in Figure 5. This ensures that both the examiner and patient are comfortable, allowing the examination is as productive as possible. Examinations should follow the classical 'look,

Summary of extrinsic muscles of the hand

Extrinsic muscles	Origin	Insertion	Nerve supply
Flexors			
Flexor digitorum superficialis	Common flexor origin on the medial epicondyle of the humerus; ulnar collateral ligament; coronoid process	Volar surface of middle phalanges	Median
Flexor digitorum profundus to index and middle finger	Proximal 3/4; of the anterior and medial surface of the ulna;	Base of the distal phalanges	Anterior interosseous (median)
Flexor digitorum profundus to little and ring finger	interosseous membrane; deep fascia of the forearm		Ulnar
Extensors			
Extensor digiti communis	Common extensor origin on lateral epicondyle of humerus	Extensor mechanism	Posterior interosseous (radial)
Extensor indicis proprius	Dorsal surface of ulna Interosseous membrane	Extensor mechanism of index finger	Posterior interosseous (radial)
Extensor digiti minimi	Common extensor origin on lateral epicondyle of humerus	Extensor mechanism of little finger	Posterior interosseous (radial)
Thumb			
Flexor pollicis longus	Volar surface of middle 1/3 of radius	Base of the distal phalanx of the thumb	Anterior interosseous (median)
Extensor pollicis longus	Dorsal surface of middle 1/3 of radius and ulna; interosseous membrane	Base of distal phalanx of thumb	Posterior interosseous (radial)
Extensor pollicis brevis	Dorsal surface of the distal 1/3 of radius; interosseous membrane	Base of proximal phalanx of thumb	Posterior interosseous (radial)
Abductor pollicis longus	Dorsal surface of middle 1/3 of radius and ulna; interosseous membrane	Radial side of base of thumb metacarpal	Posterior interosseous (radial)

Table 1

feel, move' approach. This paper will focus on the specifics in relation to important anatomical structures.

Information about flexor tendon integrity can be gained by looking at the hand. If the flexor tendons are cut there is loss of flexor tone and the digit has an extended posture at the DIPJ and PIPJ. In complete flexor tendon injury there is loss of the normal tenodesis effect (change in finger position with wrist flexion and extension). Normal flexor posture and the tenodesis effect is shown in Figure 6. The FDS and FDP tendons should be examined individually in each digit.

Flexor digitorum superficialis (FDS): to test FDS, the tendon should be isolated from FDP. The examiner holds the MCPJ, PIPJ, and DIPJ of the other digits in extension. This prevents FDP flexing the finger due to the FDP common muscle belly (see Quadriga effect). With the other digits held in extension, ask the patient to flex the PIPJ being examined (Figure 7). The presence of active flexion demonstrates there are some fibres of FDS intact, but it does not exclude a partial injury. Pain on active flexion should raise the suspicion of partial tendon injury. Repeat the process for the other digits, ensuring that FDP is isolated by holding the other digits in extension.

Note that congenital absence of FDS is present unilaterally in 6.8% of the population and bilaterally in another 6.0%.[6] If superficialis function is absent in one little finger, the probability of absence in the opposite hand is 0.64. If superficialis function is present, the probability of absence in the other little finger is 0.02 (1 in 50).

Flexor digitorum profundus (FDP): FDP is tested by resting the patients supinated hand on the examination table. Press the patient's middle phalanx into the table, and ask the patient to actively flex the DIPJ (Figure 7). Active DIPJ flexion demonstrates that there is continuity of the FDP tendon, since FDS inserts proximal to the DIPJ, on the middle phalanx. A Zone I FDP avulsion injury is termed a 'Jersey Finger' which is often described as an injury in athletes sustained when grasping onto another player's jersey. Failure to recognize and treat the injury leads to loss of DIPJ flexion, which can be difficult to manage.

Flexor pollicis longus (FPL): FPL is tested by asking the patient to flex the thumb at the IPJ, which demonstrates continuity. Loss of thumb flexion may be caused by FPL rupture, anterior interosseous nerve (AIN) palsy or C8/T1 nerve root lesion.

Quadriga effect: the quadriga effect is characterized by an active flexor lag in the fingers adjacent to a digit with a previous FDP injury or repair, usually in Zone I. It results from a functional shortening of the FDP tendon. This is usually due to over-advancement of the tendon during repair, or secondary to adhesions. Since the FDP tendons share a common muscle belly, the combined excursion of the tendons is equal only to that of the shortest tendon. Hence, when one tendon is shortened due to injury, this leads to flexor lag in the adjacent fingers, whose tendons are relatively long. This is examined by asking the patient to make a fist. The fingers adjacent to the injured digit will not reach full extension.

Summary of intrinsic muscles of the hand

Intrinsic muscles	Origin	Insertion	Nerve supply
Thenar			
Opponens pollicis	Flexor retinaculum; trapezium	Radial border of thumb metacarpal	Recurrent motor branch (median)
Abductor pollicis brevis	Flexor retinaculum; scaphoid; trapezium	Radial side of base of thumb proximal phalanx	Recurrent motor branch (median)
Flexor pollicis brevis	Flexor retinaculum; trapezium	Proximal phalanx of thumb	Recurrent motor branch (median)
Hypothenar			
Flexor digiti minimi	Flexor retinaculum; hamate	Ulnar edge of base of little finger proximal phalanx	Deep branch of ulnar
Opponens digiti minimi	Flexor retinaculum; hamate	Ulnar border of little finger metacarpal	Deep branch of ulnar
Abductor digiti minimi	Flexor retinaculum; pisiform	Ulnar edge of base of little finger proximal phalanx	Deep branch of ulnar
Others			
Dorsal interossei: four muscles	Between metacarpal shafts, i.e. first from the ulnar side of the thumb metacarpal and radial side of the index finger metacarpal	Extensor expansion and base of proximal phalanges	Deep branch of ulnar
Volar interossei: three muscles	1st — ulnar border of the index finger metacarpal; 2nd and 3rd — radial borders of the ring and little finger metacarpals respectively	Extensor lateral band	Deep branch of ulnar
Lumbricals	1st and 2nd— radial border of FDS tendon; 3rd— ulna border of middle finger FDS tendon, radial border of ring finger FDS tendon; 4th — ulnar and radial borders of the ring and little finger	Radial lateral band of the extensor mechanism, with some fibres extending to the corresponding phalanx and volar plate	Median (1st and 2nd); Deep branch ulnar (3rd and 4th)
Adductor pollicis	Transverse head: volar surface of middle finger metacarpal; Oblique head: capitate, base of index and middle finger metacarpals	Medial side of base of proximal phalanx of thumb	Deep branch of ulnar

Table 2

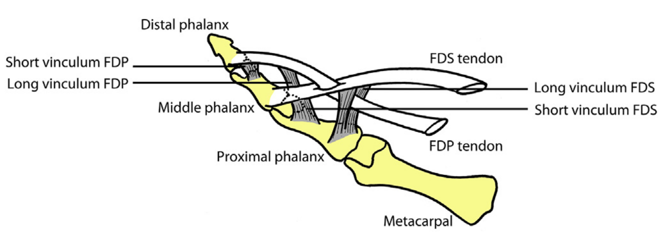

Figure 2 Flexor tendon anatomy. Blood supply to the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendons is via specialized vascular mesotendons within the tendon sheath known as vincula. Each tendon has a long and a short vinculum. These vessels receive their blood from transverse communicating branches of the digital arteries. Further supply to the tendons comes from intrinsic longitudinal vessels from the palm.

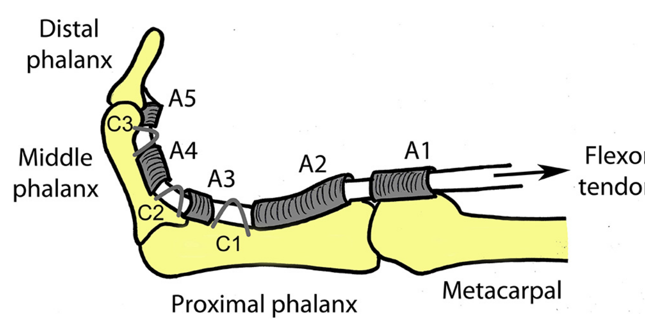

Figure 3 Pulleys of the finger. There are five annular pulleys (A1—A5) whose fibres cross the sheath perpendicular to the tendon. The A2 and A4 pulleys insert directly onto the middle and distal phalanges respectively. The A1, A3 and A5 pulleys are more flexible and insert onto to the volar plate of the metacarpophalangeal joint, proximal interphalangeal joint and distal interphalangeal joint. The position, size and strength of the A2 and A4 pulleys make these the most fundamental in preventing bow-stringing. The three cruciform 'C pulleys' (C1—C3) are interspersed between the A pulleys and their fibres create a cross-configuration over the tendons.

The effect is named after the Roman chariot which is pulled by four horses abreast, similar to the four FDP tendons. Quadriga are a popular subject of sculpture, a famous example adorns the top of the Brandenburg Gate in Berlin, Germany (Figure 8).

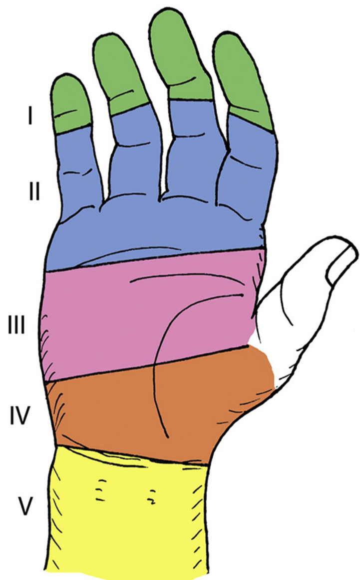

Figure 4 Flexor tendon zones. I, Distal to the insertion of flexor digitorum superficialis (FDS); II, FDS insertion to distal palmar crease; III, palm; IV, overlying carpal tunnel; V, wrist to forearm.

Figure 5 Positioning for clinical examination of the hand. The examiner sits opposite the patient with a small arm table in-between.

Surgical approaches to flexor tendons and related structures

Volar approach to finger: the most common and versatile volar approach to the finger is the 'zig-zag' incision as described by Julian Bruner in 1973.[7] This allows access to flexor tendons, digital nerves and vessels, and exposure of the flexor sheath to drain pus. The landmarks for the incision are the three transverse skin creases on the volar surface of the finger. The incision runs diagonally across the finger, changing direction at an angle of 90° at each skin crease. The diagonal incisions prevent scar contracture, which may limit flexion. The proposed incisions should be marked with a pen intraoperatively, see Figure 9. The corners of the flaps should not be too far dorsal, as this risks damaging the neurovascular bundles when the flaps are mobilized. The dissection plane is shown in Figure 11.

Volar approach for Dupuytren's disease surgery: Dupuytren's disease results in fibrosis of the normal connective tissues of the hand into pathological cords, which result in flexion contracture. The normal connective tissues are contrasted with those present in Dupuytren's disease in Figure 10. A patient with Dupuytren's disease will have fixed flexion contracture along with palpable cords or nodules. The degree of contracture should be noted for each joint.

The Bruner approach can be modified for use in Dupuytren's surgery. Due to skin contracture it is necessary to make smaller 'zig-zags,' which can allow for skin coverage once the finger is extended following Dupuytren's surgery (see Figure 9a, middle finger). The smaller flaps can be developed in a V to Y fashion to facilitate skin closure. The flaps are also raised with less or no fat due to the proximity of diseased tissue to the skin.

Midlateral approach to the finger: this can be used to access the flexor sheath, digital nerve and vessel (on the side of the incision), and access the phalanges for fracture fixation. Landmarks for this approach are the IPJ skin creases. This approach is shown in Figure 11, contrasts it to the Bruner approach described in Figure 9.

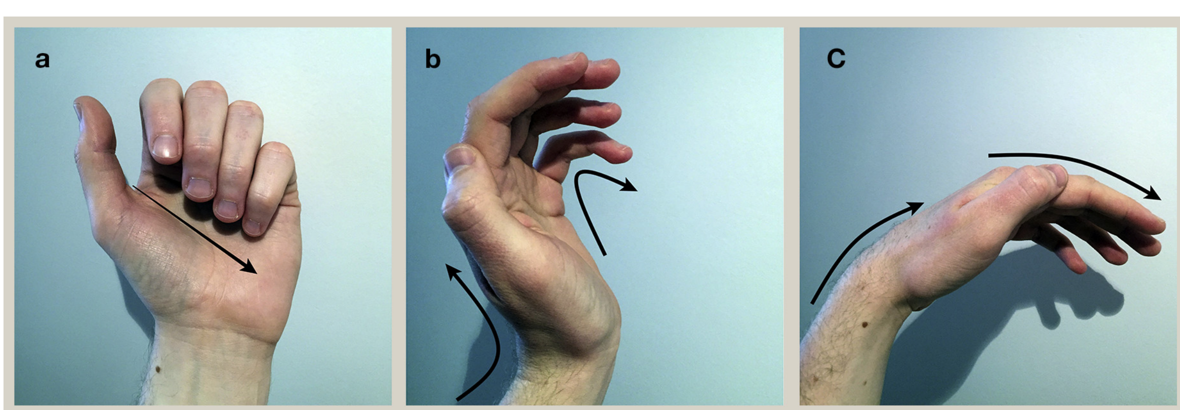

Figure 6 Flexor cascade and tenodesis effect. (a) Look for the normal cascade of the hand from the front, flexion increases from index to little finger sequentially. (b) Look from the side and note the degree of finger flexion with the wrist still extended — the fingers are relatively flexed. (c) Passively flex the patient's wrist and note that finger flexion will decrease.

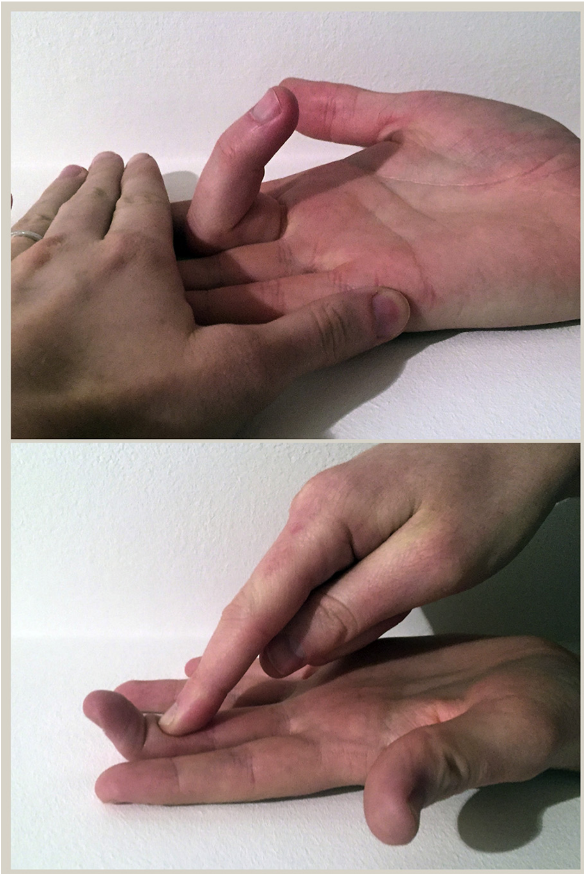

Figure 7 Flexor tendon examination. Top: testing flexor digitorum superficialis (FDS). With the other digits held in extension, ask the patient to flex the proximal interphalangeal joint of the digit being examined. Bottom: testing flexor digitorum profundus (FDP). Press the patient's middle phalanx into the table, and ask the patient to actively flex the distal interphalangeal joint.

Extensor tendons

Anatomy

The long extensor tendons of the fingers and thumb arise from muscle bellies in the posterior forearm. Extensor digitorum communis (EDC), extensor indicis proprius (EIP) and extensor digiti minimi (EDM) pass into the hand beneath the extensor retinaculum in the wrist, forming the extensor mechanism of the digits. In the dorsum of the hand, the extensor tendons are connected by juncturae tendinum, fibrous bands that lie in an oblique direction between the tendons. Again, there is significant anatomical variability in the arrangement of these tendinum.

At the MCPJ of the index finger EIP joins the EDC tendon complex, allowing independent extension of the index finger. This gives the ability to point the index finger with the other digits flexed, which is not possible for the middle and ring fingers. The little finger also has an accessory extensor; EDM. EIP and EDM are clinically useful for tendon transfers in the context of EDC rupture. As the extensor tendons pass over the MCPJ, their central alignment is maintained by the sagittal bands. These bands are components of the extensor hood and are comprised of transverse fibres surrounding the dorsal aspect of the MCPJ. They attach on to the volar plate anteriorly and coalesce with the accessory collateral ligament over the volar surface.[8] The fibres are dynamic in their orientation and alter throughout the range of movement of the MCPJ to prevent the slippage of the extensor tendons during MCPJ flexion. They also prevent tendon bowstringing when the MCPJ is hyperextended.

At each PIPJ, the tendon of EDC splits into three slips, one central and two lateral slips. The central slips insert onto the base of the middle phalanx. The two lateral slips run either side of the PIPJ and are joined by tendons from the intrinsic hand muscles. These are then known as medial and lateral conjoined tendons, or lateral bands, which amalgamate over the DIPJ into the terminal tendon and insert onto the base of the distal phalanx. Some

Figure 8 The quadriga on top of the Brandenburg Gate in Berlin (Germany) at night. (By א (Aleph) Creator: Johann Gottfried Schadow (Own work) [CC BY-SA 2.5 (https://creativecommons.org/licenses/by-sa/2.5)]).

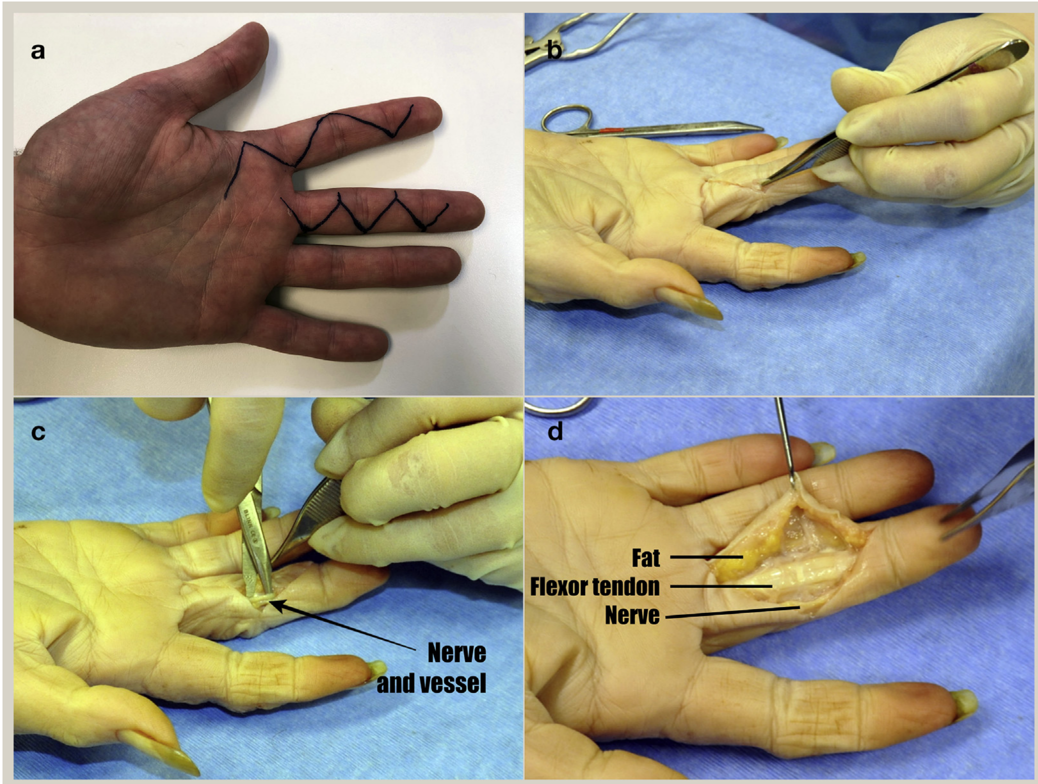

Figure 9 Volar Bruner approach to the finger. (a) Incision is marked on the index finger using flexor creases as landmarks to change direction. The modification for use in Dupuytren's surgery is shown on the middle finger. (b) Starting at the apex, reflect the skin flaps along with the underlying fat. (c) After incising the skin use blunt dissection to identify the neurovascular bundle. Then work towards the midline of the finger until the flexor sheath is reached, then elevate a full thickness flap of skin and fat off the sheath. (d) Ensure the flexor sheath has been reached before widely mobilizing the flaps, as this ensures thick flaps are raised. This reduces the risk of flap necrosis. Deep dissection depends on the structures of interest. If necessary, the approach can easily be extended into the palm.

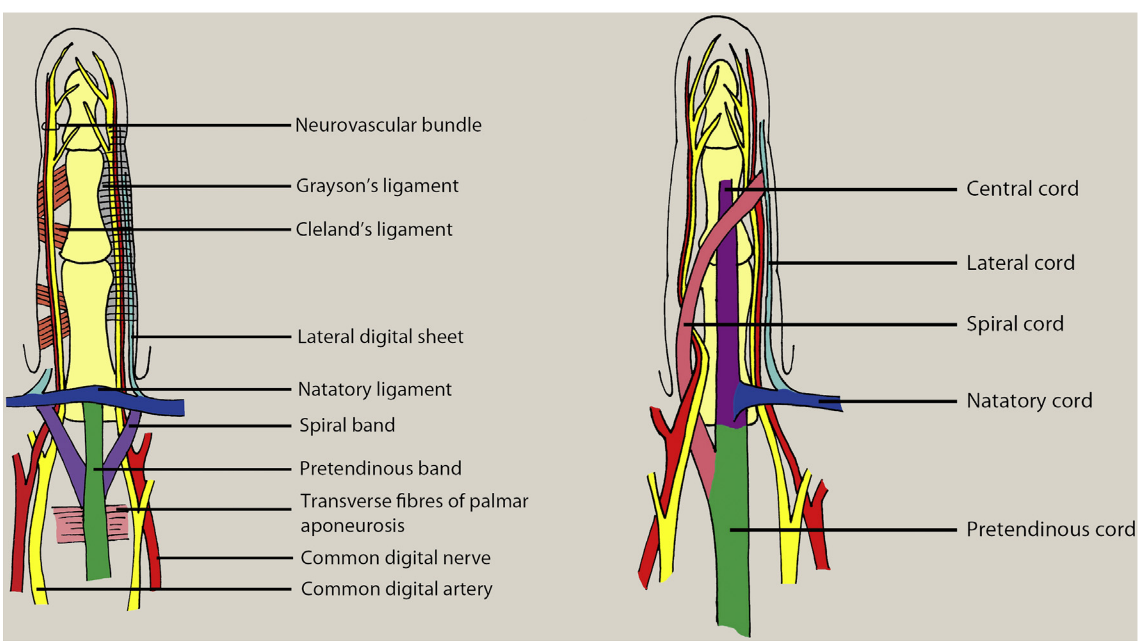

Figure 10 Pathoanatomy of Dupuytren's disease. Left: Normal digit anatomy. Skin overlying the palm of the hand is strongly adhered to the underling bone to stop slippage during movement of the digits and to improve grip. These connections are formed by retention ligaments which are continuous with the fascia of the digits and palm. Within the digits, the fascia is divided into; Cleland's ligaments (found dorsal to the neurovascular bundle) and Grayson's ligaments (volar), as well as the lateral digital sheath. The palm also has similar fibres named the spiral band, natatory ligaments and pretendinous bands. Right: pathological anatomy of Dupuytren's disease. The development of Dupuytren's disease involves the coalescence and thickening of the fascial bands leading to flexion contracture of the underlying joints. These thickened bands are named cords and follow a different arrangement to the normal ligaments and bands. Note the spiral cord which displaces the neurovascular bundle volarly. The disease only affects longitudinally oriented fibres, so Cleland's ligaments and the transverse fibres of the palmar aponeurosis are not affected.

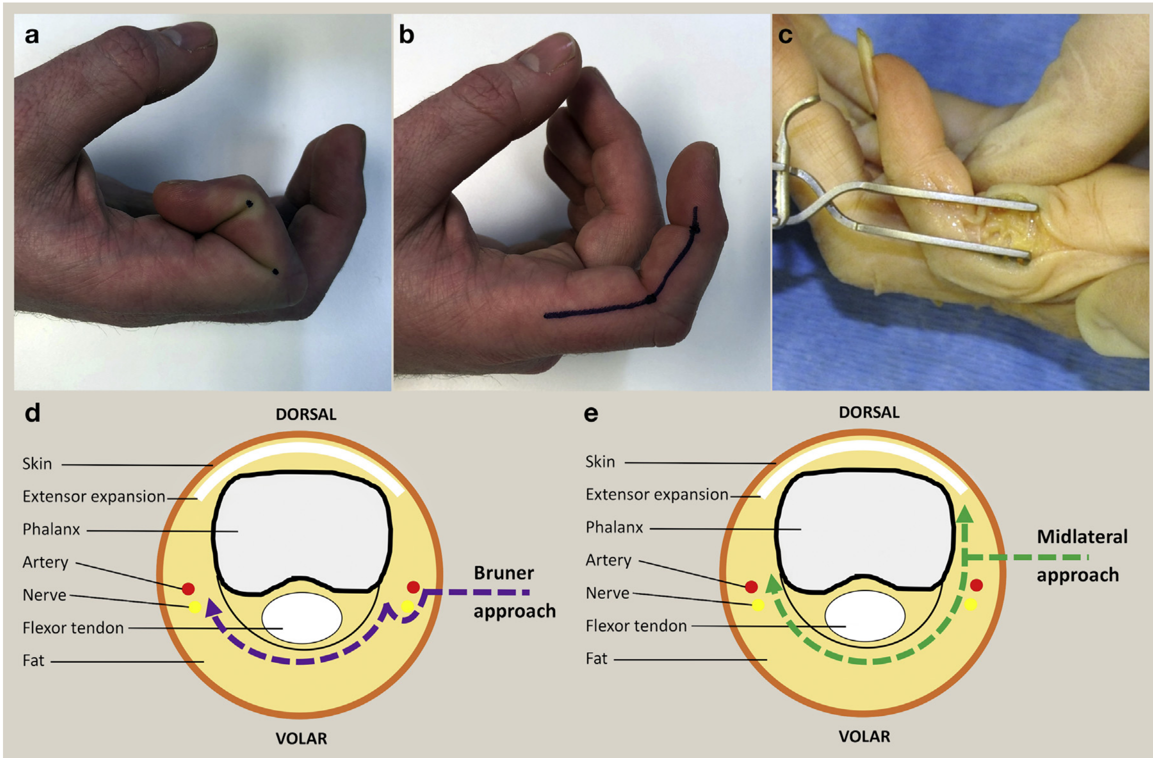

Figure 11 Midlateral approach to the finger and dissection planes. (a) With the finger flexed, mark the most dorsal point of the skin creases. (b) Extend along the same line towards the fingertip or metacarpophalangeal joint. (c) Develop a volar skin flap by dissecting the subcutaneous fat in line with the incision. Continue the dissection towards the midline of the finger. Identify the neurovascular bundle and stay dorsal to it. Since the fat covering the proximal interphalangeal joint (PIPJ) is relatively thin, take care not to enter the PIPJ. As the flaps are elevated the neurovascular bundle will be within the volar flap. The flexor sheath can be incised longitudinally to access the tendons, or by longitudinal dissection the neurovascular bundles can be exposed in the volar flap. Note that if the initial incision is too volar, the neurovascular bundle is at risk. The incision should be just dorsal of the midlateral aspect of the finger. It is difficult to extend the approach beyond the finger into the palm. (d) The 'zig-zag' Bruner approach identifies the neurovascular bundle and stays volar to it (purple line). (e) The midlateral approach begins dorsal to the neurovascular bundle and keeps the bundle in the volar flap tissue (green line). It can also be extended dorsally.

fibres from the intrinsic muscle tendons also pass dorsally, combining with the central slip (Figure 12).

The lateral bands are held in place by three groups of ligaments. The transverse retinacular ligaments (TRL) pass laterally from the tendons to insert onto the PIPJ volar plate. These ligaments prevent dorsal slippage of the lateral bands during extension, stopping hyperextension of the PIPJ as seen with a swan-neck deformity. Oblique retinacular ligaments (ORL) are positioned distal to the TRL over the dorsal aspect of the DIPJ. They originate on the flexor sheath, passing beneath the TRL to join with the lateral band distally over the middle phalanx.[9]

Finally, the triangular ligament lies dorsally between lateral bands to prevent volar subluxation during flexion of the DIPJ. Failure of the triangular ligament can lead to a boutonnière deformity.

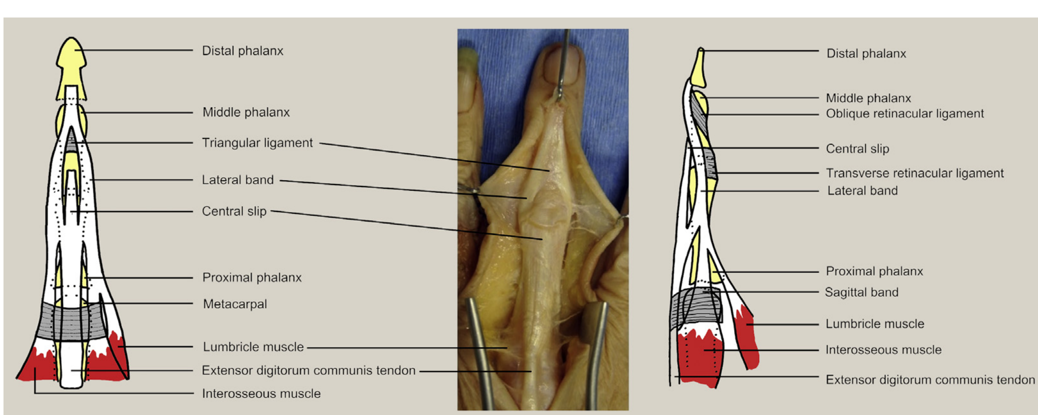

Figure 12 Diagram of the extensor expansion in the digits. Left: dorsal view. Central: anatomical specimen dorsal view. Right: lateral view.

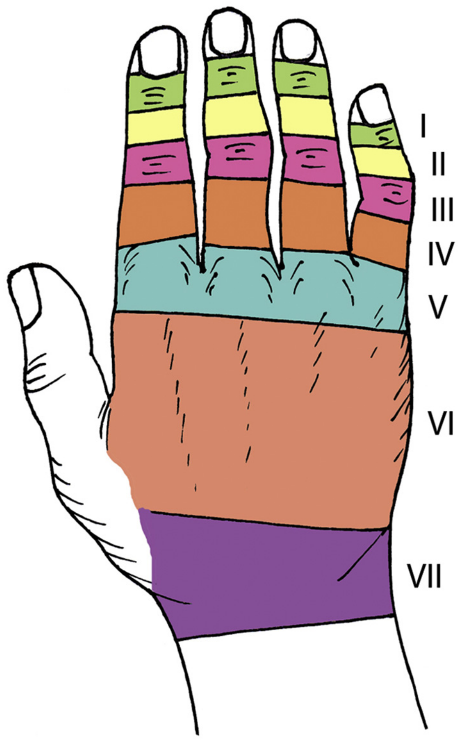

Figure 13 Extensor tendon zones. I, distal interphalangeal joint; II, middle phalanx; III, proximal interphalangeal joint; IV, proximal phalanx; V, metacarpophalangeal joint; VI, metacarpals; VII, carpals.

As with the fingers, a sagittal band of the thumb surrounds the dorsal aspect of the MCPJ to stabilize the tendons. These bands originate from adductor pollicis tendon, the A1 pulley and the volar plate on the ulnar aspect and from the abductor pollicis brevis tendon on the radial side.

Zones of the extensor tendons

The extensor tendons are divided into seven zones which relate to the underlying anatomical landmarks, as demonstrated in Figure 13.

Clinical examination of the extensor mechanism

When examining the extensor mechanism of the fingers it is important to know which anatomical structure is responsible for extending each joint. This can then be used to determine which structures are damaged and at what level. Extension at the MCPJ is performed exclusively be the extrinsic extensor tendons. Loss of MCPJ extension is caused by injury to the extrinsic extensor tendon at or proximal to the MCPJ. Examine the patient by checking the power of active extension at each MCPJ of a semi-flexed finger. Compare with the other hand. Reduced power may be a sign of a partial injury to the extensor tendon.

In contrast, PIPJ extension is primarily due to intrinsic muscle action. The PIPJ can be extended using the extrinsic muscles in a patient with intrinsic muscle palsy only if MCPJ hyperextension is blocked. It is not possible to extend the PIPJ without extending the DIPJ in the normal hand.

If the PIPJ extends normally but the DIPJ remains flexed, suspect an injury to the terminal extensor tendon around its insertion (Zone I). This is a mallet deformity. Ask the patient to slowly extend their fingers from a clenched fist. The examiner should see each finger gradually uncurling into full extension. If there is any doubt, extension power can be tested at each joint. A mallet deformity will be apparent by simply asking the patient to extend all of their fingers out straight. If the DIPJ is flexed but the other joints are extended, then this is likely due to a mallet deformity (Zone I FDP injury).

Central slip: injury to the central slip may not be apparent on gross assessment of finger extension, since PIP extension will still occur due to the integrity of the lateral bands. However, a neglected injury may lead to a boutonnière deformity as the lateral bands sublux, causing PIPJ hyperextension with DIPJ flexion.

Flexion of the PIPJ advances the central slip distally (since it inserts on the dorsum of the middle phalanx). This pulls its proximal attachments distally also, which slackens the lateral bands, as demonstrated in Figure 14. This slackening is designed to facilitate full flexion of the DIPJ when the PIPJ is fully flexed.

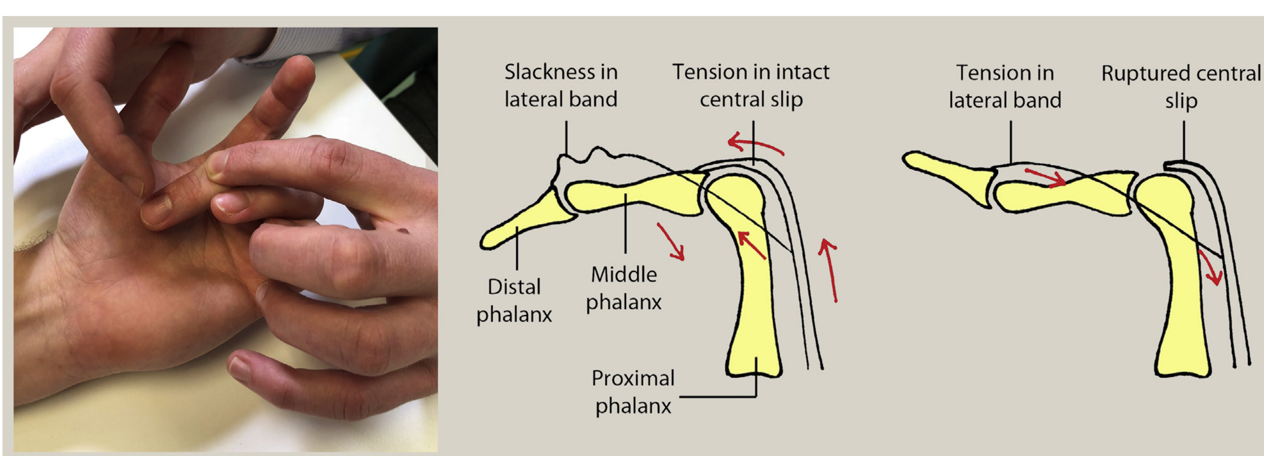

Figure 14 Central slip testing. Left: With the patient's hand supine on the table, stabilize the metacarpophalangeal and proximal interphalangeal joints at 90° as shown. The distal interphalangeal joint (DIPJ) should remain floppy. Centre: in the normal finger the advancement of the central slip during finger flexion detentions the lateral bands so the DIPJ is floppy. Right: in central slip rupture, the lateral bands are tight leading to DIPJ extension.

When the central slip is intact it is impossible to actively extend the DIPJ with the PIPJ is fully flexed. This is due to slack in the lateral bands. This is the basis of Elson's test for the central slip. The examiner passively flexes the patient's PIPJ to 90° over the edge of the table top. Ask the patient to actively extend the finger whilst the examiner resists PIPJ extension. Central slip rupture leads to loss of extension power at the PIPJ, with paradoxical significant power or hyperextension at the DIPJ.

It may be more practical to perform the test with the hand supine, whilst the examiner stabilizes the finger as shown in Figure 14. In the normal finger the DIPJ should remain floppy.

Extensor indicis proprius (EIP), extensor digiti minimi (EDM) and extensor pollicis longus (EPL): the little finger and index finger have dual extensor tendons which should be tested. To do this, ask the patient to make a 'Rock sign' by flexing the middle and ring fingers whilst extending the index and little fingers. (Figure 15). This action deactivates the EDC tendons. Any extensor lag should raise the suspicion of EIP or EDM injury, and may be important in the context of tendon transfers for reconstruction.

EPL tendon is a powerful extensor of the IPJ of the thumb. However, IPJ extension is not a reliable test of EPL since abductor pollicis brevis and adductor pollicis also insert onto the extensor hood and can contribute to IPJ extension in the thumb.

To test EPL, ask the patient to place their hand flat on the table and raise the thumb towards the ceiling. Retropulsion of the thumb is the visualized movement, and the EPL tendon can usually be seen under tension on the back of the hand (Figure 15).

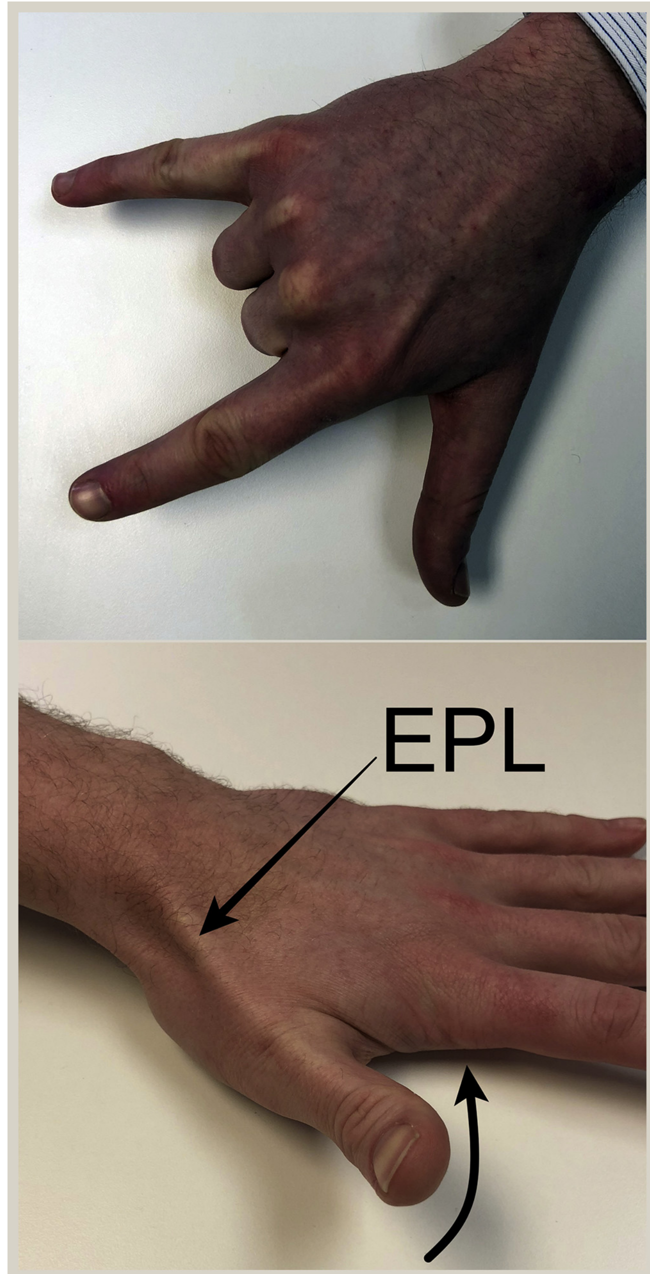

Figure 15 Testing the extensor tendons to the thumb, index and little fingers. Top: the 'rock' sign is formed by asking the patient to extend their index and little finger with the middle and ring finger flexed. Bottom: to view extensor pollicis longus function ask the patient to lift their thumb off the table.

Extensor approaches

The extensor surface of the digit is less prone to scar contracture, and there are a wide range of safe incision patterns which facilitate access to the extensor mechanism, joints and bones. The skin is relatively thin compared to the volar surface of the finger, and there is very little subcutaneous tissue to dissect before the extensor mechanism is encountered. The type of incision depends on the degree of exposure required. For extensive longitudinal exposure, a straight longitudinal incision in the midline of the finger can be used. However, a more elegant solution is to use an elongated 'S' shaped incision, which avoids scars crossing over the most taught skin of the joints. Examples are shown in Figure 16.

The DIPJ can be exposed through a wine cup or 'H' shaped incision. Access to the PIPJ may be better achieved through a short lazy 'S' incision or semilunar incision. To gain access to the joint, a 'V' shaped flap is raised incorporating the central slip from proximal to distal. Joint flexion will then allow visualization of the joint.

The nail

Anatomy

The hard, external portion of the finger or thumb nail is known as the nail plate and is made from anucleate, keratin-filled squames. The lunula is the paler, crescent shape at the junction between the nail plate and the nail fold. The dorsal layer of the epidermis of the fingertip extends out from the nail fold to form the eponychium, or cuticle. Most distally on the fingertip, the hyponychium is the portion of the epidermis lying beneath the free edge of the nail plate. It functions as a barrier to prevent infection entering under the nail plate. The epidermis surrounding the nail plate medially and laterally is the paronychium. The function of the nail plate is to provide counter-pressure during a pinch grip, as well as to assist with picking up flat objects.

The nail plate lies on the nail bed or matrix. This is a specialized form of epithelium that is responsible for the growth of the nail plate and is comprised of the germinal matrix

Figure 16 Potential approaches to the extensor surface of the digit.

proximally, and the sterile matrix distally. The germinal matrix produces the majority of the substance of the nail, and damage to this area will lead to loss of the nail. The sterile matrix creates a layer of cells, which adhere the nail to the nail bed, and loss of this leads to nail deformities. Deep to the nail bed, the dermis is anchored to the periosteum of the distal phalanx through fibrous tissue septa. Fingertip anatomy is shown in Figure 17. The fingertips are susceptible to specific infections due to their anatomy and these are discussed in Box 1.

Intrinsic muscles

Anatomy

The intrinsic muscles of the hand are the lumbricals, the dorsal and palmar interossei, and the thenar and hypothenar muscles. The lumbricals are unique muscles in that they originate and insert onto tendons. They lie in a plane dorsal to the palmar aponeurosis and their main action is to antagonize the action of FDP, extending the IPJ and flexing the MCPJ.

Fingertip infections

Paronychia

Acute paronychia is infection of the soft tissue fold around the fingernail. An abscess forms along the nail fold, which may extend below the nail plate, or even track volarly into the pulp space (see felon). Very early infection may be managed with antibiotics alone. Surgical management is planned to address the location of the collection in more extensive disease. One method is to release along the perionychial sulcus, extending proximally to the level of the nail base. If there is extensive eponychial involvement, a double incision may be utilized. If the abscess extends below the nail plate, consider removing a portion of the nail.

Felon

The finger pulp is divided into a latticework of many separate compartments by vertical trabeculae. These arise from the periosteum of the distal phalanx and insert on the epidermis. They give structural support to the pulp during pinch and grasp. The resulting compartments are filled with fat globules and eccrine sweat glands. A felon is a subcutaneous abscess of the finger pulp which involves the multiple septal compartments of the palmar pad.

Because of the closed septal anatomy infection leads to increased pressure and ischaemic pain. Surgical decompression is usually required. Incisions should respect the digital neurovascular bundles, not cross the distal interphalangeal joint, and not violate the flexor sheath. A unilateral longitudinal approach, just volar to the phalanx, may be used. It is important to break the internal septae to release all compartments.

Box 1

The first and second lumbricals are usually unipennate and arise from the radial border of the FDS tendon to the index and middle fingers. The third is commonly bipennate and originates on the ulnar border of the middle finder FDS and the radial border of the ring finger FDS tendon. A similar arrangement is seen with the fourth, in that it is usually bipennate and arises

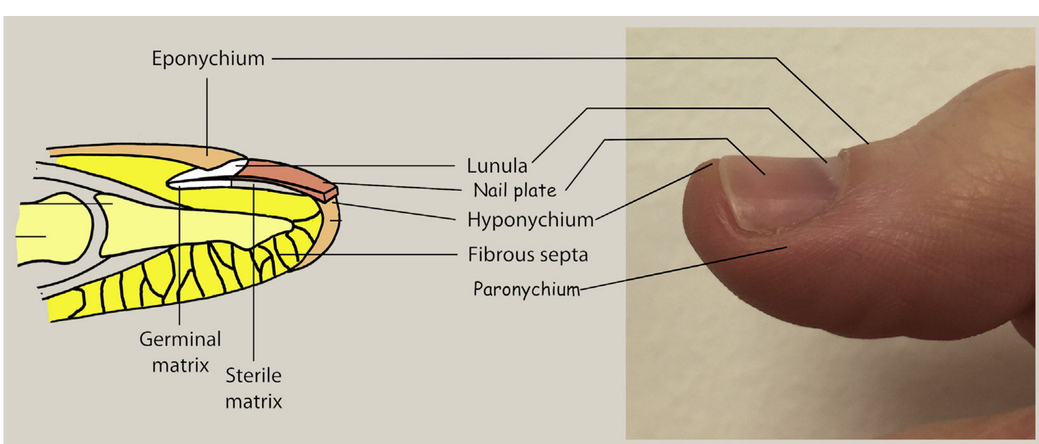

Figure 17 Anatomy of the fingertip shown in sagittal section (left) compared with a clinical photograph (right).

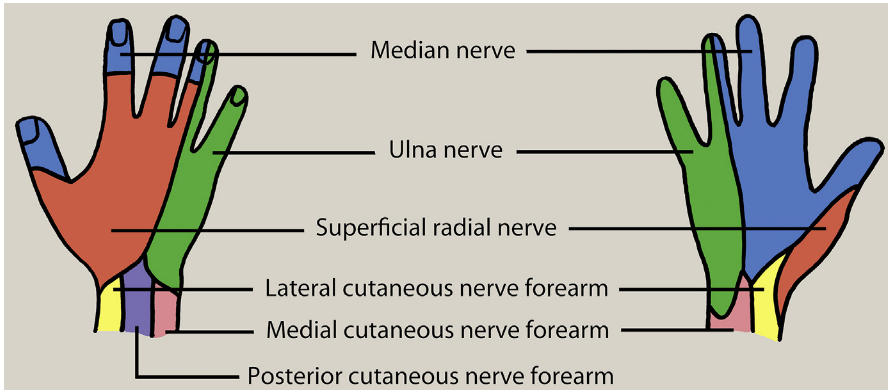

Figure 18 Cutaneous innervation of the hand.

from the adjacent ulnar and radial borders of the ring and little finger. The muscle fibres travel in an oblique, longitudinal direction, to insert onto the radial lateral band of the extensor mechanism, with some fibres extending to the corresponding phalanx and volar plate.[10]

The interossei are two groups of three or four muscles that lie between the shafts of the metacarpals. There is a palmar group and a dorsal group. The four dorsal interosseous (DI) muscles are bipennate and originate from the shafts of the metacarpals. The first from the ulnar side of the thumb metacarpal and radial side of the index finger metacarpal, the second from the ulnar side of the index finger metacarpal and the radial side of the middle finger metacarpal and so forth. Each muscle usually has two heads, one superficial (dorsal) and one deep (palmer).

As with many components of the hand, there is considerable variation in the reported arrangement of the interossei, particularly with regard to their insertion points.[10] It is usually stated that the superficial heads of the first and second DI insert radially onto the base of the respective proximal phalanx and the third and fourth onto the ulnar side of proximal phalanges. The deeper heads, along with the palmar interosseous, create the lateral bands of the extensor expansion. For example, the deep head of the second DI forms the radial lateral band of the middle finger, with the third DI forming the ulnar lateral band. The main action of the DI is to abduct the digits.

There are usually three palmar interossei (PI). They are adductors of the fingers and thus are positioned accordingly. The first PI originates on the ulnar border of the index finger metacarpal, and the second and third on the radial borders of the ring and little finger metacarpals respectively. The insertion of each of the interossei is to the extensor lateral band on the same side of proximal phalanx in which the muscle arises.

The arrangement of muscles and tendons in the little finger, as with the thumb, requires further explanation. Abduction of the little finger is carried out by the abductor digiti minimi (ADM) hypothenar muscle which arises from the pisiform and the tendon of flexor carpi ulnaris (FCU). The insertion of the ADM is to the ulnar border of the little finger proximal phalanx and the ulnar lateral band of the extensor mechanism.

Examination of intrinsic muscles

The intrinsic muscles are closely linked to the extensor and flexor tendons in the hand, so it is good practice to examine the intrinsic muscles in conjunction with these tendons.

Intrinsic tightness: intrinsic hand muscles act to flex the MCPJ and extend the IPJs, and therefore tight intrinsic muscles lead to a classical posturing of the hand. The MCPJ are flexed, whilst the PIPJ and DIPJ are extended. The Bunnel test is designed to differentiate intrinsic from extrinsic tightness. The examiner compares the patients passive range of PIPJ flexion with the MCPJ extended, and then flexed. If the PIPJ joint range of movement is less with the MCPJ extended, then the intrinsics are likely to be tight.

If intrinsic tone is lost, such as in a patient with an ulnar nerve palsy, then the patient will have a claw hand posture, with hyperextended MCPJs, and flexed IPJs.

Nerve supply

Anatomy

The motor and sensory nerve supply to the hand and digits is via the median, ulnar and radial nerves and their branches. These nerves arise from the brachial plexus from the C5-T1 nerve roots. The sensory distribution of the nerves is shown in Figure 18.

Examination

Peripheral nerve examination of the hand is covered in some detail recently.[1] Sensation should be tested according to peripheral nerve distribution and also dermatomes, as shown in the diagrams. This can help the examiner to differentiate a peripheral nerve compressive neuropathy from a nerve root lesion. Assessing the motor function of the digit should help differentiate trauma to individual tendons or digits from neurological disturbances.

Conclusion

Clinical assessment of the hand can seem complex. With a thorough understanding of the functional anatomy, the clinician is much more likely to be able to determine what pathology is leading to the patient's symptoms. A systematic, methodical approach – combined with a solid grounding in anatomy – is key to the successful understanding and assessment of the hand. ◆

REFERENCES

1 Newton AW, Hawkes DH, Bhalaik V. Clinical examination of the wrist. *Orthop Traumatol* 2017; **31:** 237–47.

2 Williams EH, McCarthy E, Bickel KD. The histologic anatomy of the volar plate. *J Hand Surg* 1998; **23:** 805–10.

3 Bowers WH, Wolf JW, Nehil JL, Bittinger S. The proximal interphalangeal joint volar plate. I. An anatomical and biomechanical study. *J Hand Surg* 1980; **5:** 79–88.

4 Zafonte B, Rendulic D, Szabo RM. Flexor pulley system: anatomy, injury, and management. *J Hand Surg* 2014; **39:** 2525–32.

5 Bayat A, Shaaban H, Giakas G, Lees VC. The pulley system of the thumb: anatomic and biomechanical study. *J Hand Surg* 2002; **27:** 628–35.

6 Townley WA, Swan MC, Dunn RLR. Congenital absence of flexor digitorum superficialis: implications for assessment of little finger lacerations. *J Hand Surg Eur* 2010; **35:** 417–8.

7 Bruner JM. Surgical exposure of flexor tendons in the hand. *Ann R Coll Surg Engl* 1973; **53:** 84–94.

8 Young CM, Rayan GM. The sagittal band: anatomic and biomechanical study. *J Hand Surg* 2000; **25:** 1107–13.

9 Ueba H, Moradi N, Erne HC, Gardner TR, Strauch RJ. An anatomic and biomechanical study of the oblique retinacular ligament and its role in finger extension. *J Hand Surg* 2011; **36:** 1959–64.

10 Eladoumikdachi F, Valkov PL, Thomas J, Netscher DT. Anatomy of the intrinsic hand muscles revisited: part II. *Lumbricals Plast Reconstr Surg* 2002; **110:** 1225–31.

