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Hand tendon injuries

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Abstract

This article provides a comprehensive overview of hand tendon injuries. It has been tailored towards healthcare professionals who will be the first to assess these injuries and instigate appropriate management. It discusses the essential hand anatomy to be aware of, how to assess tendon injuries, their initial management and also the definitive surgical interventions used, if required. Rehabilitation techniques are also discussed, as this is also key to good functional outcomes. Missed injuries, or delay in their diagnosis and referral to specialist hand surgeons, can cause a large amount of morbidity for patients and therefore it is important that they are picked up in a timely manner.

Key words: Extensor; Flexor; Hand; Tendon

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Introduction

Injuries to the hands are extremely common and account for 20–30% of presentations to urgent care centres or emergency departments (Miranda et al, 2016; Ishak et al, 2019). The anatomy of the hand is complex. It is essential that front-line assessors are able to accurately diagnose and manage injuries acutely, direct patients towards optimal treatment pathways and ultimately help them to achieve good functional outcomes. Tendon injuries are the second most common injury seen in the hand (British Society for Surgery of the Hand, 2020a), with an incidence of 33 per 100 000 people (Jong et al, 2014). They can be caused by penetrating or blunt trauma, crush injuries or attrition ruptures secondary to other pathology.

Single tendon injuries are more common than multiple, and extensor tendon injuries occur more frequently than flexor injuries. For lacerations, accidental injuries tend to occur to the non-dominant hand, as a result of a person holding an implement in their other hand, whereas in non-accidental injuries, lacerations are more common to the dominant hand as it is that which is held out to protect oneself (Magee et al, 2016). Early primary repair of tendons is now advocated (Coats et al, 2005) and this should ideally take place within 4 days (British Society for Surgery of the Hand, 2020b). If there is segmental tendon loss or scarring, staged procedures may be required.

Anatomy

Flexors

The flexor tendons originate from muscle bellies on the volar forearm and have specific distal bony attachments. Figure 1 demonstrates how in each finger, the flexor digitorum superficialis tendon inserts on the base of the middle phalanx, facilitating proximal interphalangeal joint flexion. They each have a defined individual muscle belly and lie superficial to the flexor digitorum profundus tendons until they bifurcate at the level of the proximal phalanx creating two slips. These slips pass around underneath the respective flexor digitorum profundus tendon, allowing it to seemingly pass through the centre of it. The flexor digitorum profundus tendon then travels distal to insert on the base of the distal phalanx, where it facilitates distal interphalangeal joint flexion.

In the thumb, the flexor pollicis longus inserts onto the base of the distal phalanx, facilitating interphalangeal joint flexion. This tendon has a higher chance of retraction if cut, because of the absence of vincula, which are fibrous attachments connecting the flexor digitorum superficialis and flexor digitorum profundus tendons to each other and to the underlying bone.

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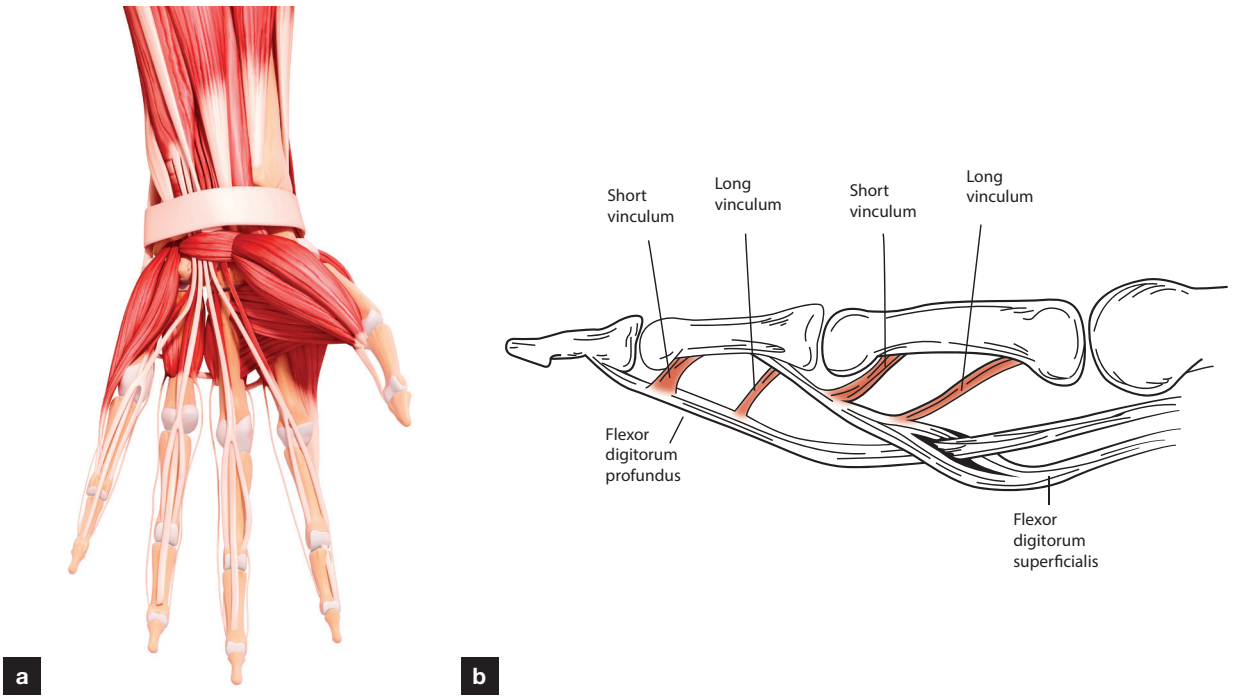

Figure 1. a. Overview of flexor tendon anatomy. b. Detailed flexor tendon anatomy in a finger.

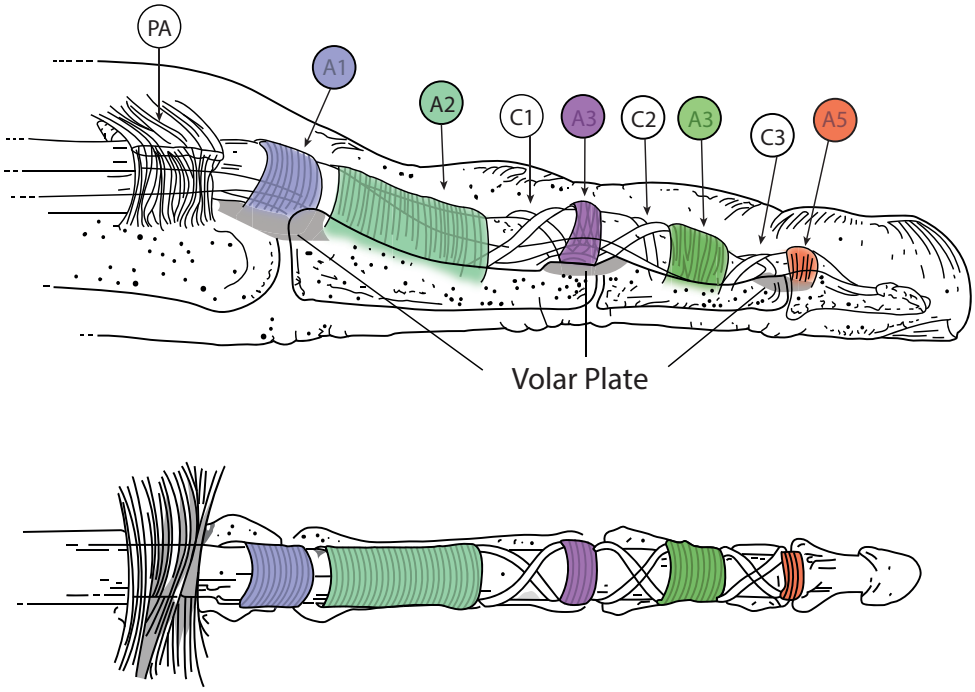

Figure 2. Anatomy of flexor tendon pulleys within a finger. A = annular pulley; C = cruciate pulley; PA = palmar aponeurosis.

Figure 2 demonstrates how the flexor tendons are contained within their own synovial sheath and run through a series of pulleys that help to prevent 'bowstringing' on digit flexion. Within the fingers, there are five annular and three cruciate pulleys and in the thumb there are two annular pulleys and one oblique pulley. At the wrist, the flexor carpi ulnaris inserts onto the fifth metacarpal, pisiform and hook of the hamate, with the flexor carpi radialis inserting onto the second and third metacarpals.

It is helpful to use the internationally recognised five flexor zones when describing sites of injury (modified from the seven zones originally described by Verdan (1972)), as illustrated in Figure 3 and Table 1. The most commonly seen flexor injury is in zone 2 of

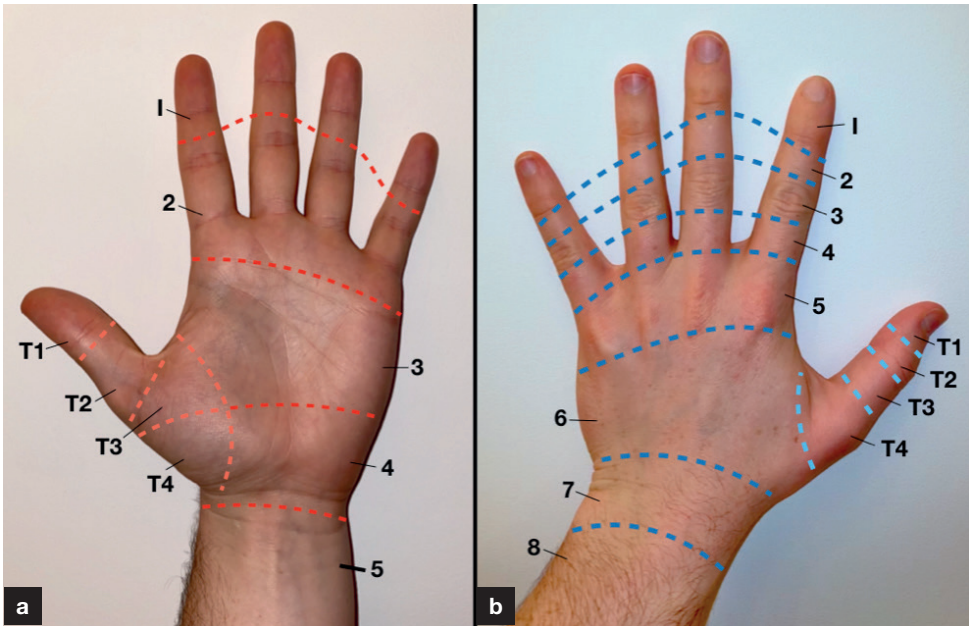

Figure 3. a. Flexor and (b) extensor zones.

the index finger (Jong et al, 2014). Associated injuries can be difficult to assess and often rely on surgery to diagnose. Gibson et al (1999) found that in up to half of zone 5 injuries, patients had three or more additional injuries not identified in the initial examination.

Extensors

The anatomy of the extensor mechanism is more complex than the flexor counterpart, as demonstrated in Figure 4. The extensor tendons of the fingers include the extensor digitorum communis, extensor indicis proprius and extensor digiti minimi. They originate from their respective muscle bellies in the dorsal forearm and travel under the extensor retinaculum within specific compartments. The extensor digitorum communis tendons insert onto the bases of the middle phalanx (as the 'central slip') and distal phalanx (site of fusion of the two lateral slips).

Table 1. Flexor zones and associated injury patterns

Flexor zone (T=thumb)	Boundaries	Associated injury pattern
Zone 1	Distal to flexor digitorum superficialis insertion	Closed avulsions (eg jersey finger, see later)
T1	Distal to interphalangeal joint	Penetrating wounds
Zone 2	Flexor digitorum superficialis insertion to distal palmar crease (approximately A1 pulley)	Penetrating wounds (most common type in zone 2)
T2	Flexor digitorum superficialis insertion to metacarpophalangeal joint level	Blunt or crush injuries (ie avulsion) Attrition ruptures (these are rare, eg bony spur in rheumatoid arthritis, previous severe trauma or infection)
Zone 3	Distal palmar crease to distal border of carpal tunnel	Penetrating wounds (often associated with neurovascular injury)
T3	Distal palmar crease to thenar eminence	
Zone 4 and T4	Within the carpal tunnel	Attrition ruptures (eg Mannerfelt syndrome, if flexor pollicis longus is ruptured by a bony spur in the carpal tunnel)
Zone 5 and T5	Proximal to carpal tunnel	Penetrating wounds (often when retracting a hand through a broken glass window or deliberate self harm)

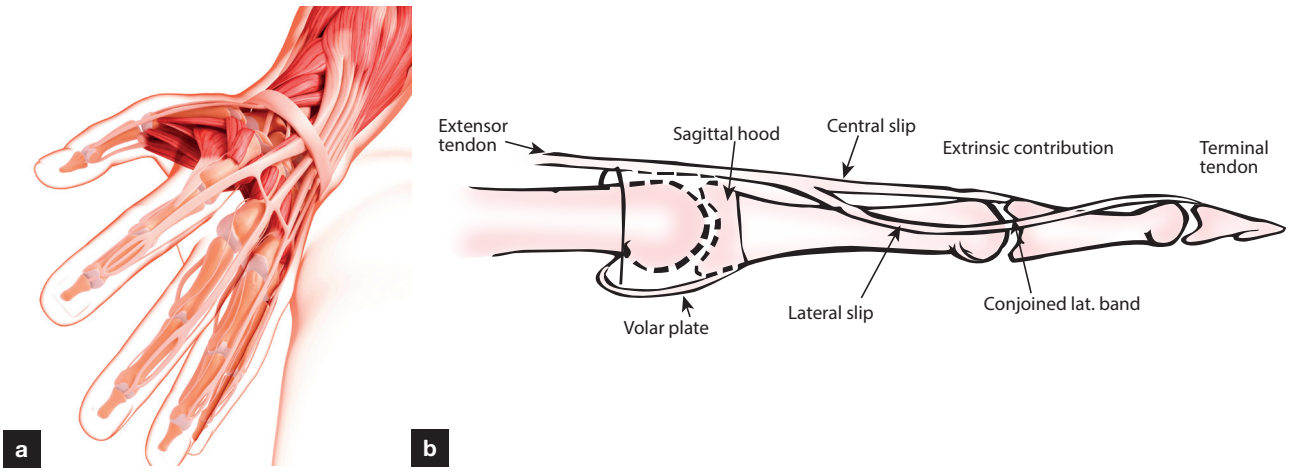

Figure 4. a. Overview of the extensor tendon anatomy. b. Detailed extensor tendon anatomy in a finger.

There is also a supporting infrastructure of ligaments, sagittal bands, juncturae and muscular attachments to consider.

Within the thumb, the extensor pollicis longus and extensor pollicis brevis insert onto the bases of the distal and proximal phalanges respectively. The abductor pollicis longus inserts onto the first metacarpal.

At the wrist, the extensor carpi ulnaris inserts onto the fifth metacarpal, with the extensor carpi radialis longus and brevis tendons inserting onto the second and third metacarpals respectively.

Figure 3 and Table 2 illustrate the eight injury zones on the dorsum of the hand and forearm, with the odd numbered zones relating to injuries over joints (Strauch, 2011). The most commonly seen extensor injury is at zone 3 of the index finger (Jong et al, 2014).

Types of tendon injury

Acute lacerations

Lacerations to tendons can be complete or partial. The common types of injury are demonstrated in Figure 5; tendons can be damaged in a guillotine-type fashion (eg from a knife), have segmental loss (eg from a rotating circular saw) or be crushed.

Table 2. Extensor zones and associated injury patterns

Extensor zone (T=thumb)	Boundaries	Associated injury pattern
Zone 1	Distal to and over distal interphalangeal joint	Mallet finger
T1	Distal to and over interphalangeal joint	■ Closed avulsion ■ Penetrating wound
Zone 2	Over middle phalanx	In general:
T2	Over proximal phalanx	■ Inability to extend the digit or wrist ■ Penetrating wounds ■ Closed avulsions
Zone 3	Over proximal interphalangeal joint	
T3	Over metacarpalphalangeal joint	
Zone 4	Over proximal phalanx	Specific injuries:
T4	Over carpometacarpal joint	■ Boutonnière deformity (zone 2) ■ 'Fight bites' (usually zone 5)
Zone 5	Over metacarpalphalangeal joint	
Zone 6	Over metacarpals	
Zone 7	Over extensor retinaculum	
Zone 8	Over forearm	

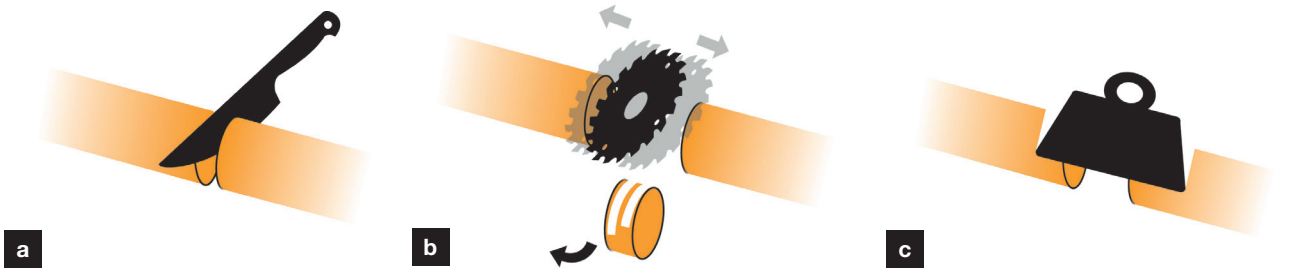

Figure 5. Examples of types of tendon injury. a. Guillotine type. b. Segmental loss of the tendon (eg from a rotating saw blade, as a result of vibration in the x-axis). c. Crush injury.

Figure 6. Radiograph displaying a jersey finger abnormality, with a large avulsion fracture and dorsal subluxation of the distal phalanx (as a result of the action of the extensor digitorum communis tendon).

Other specific injuries

Jersey finger

This is an avulsion injury of the flexor digitorum profundus from its distal phalanx insertion. This is commonly a sporting injury resulting from sudden hyperextension at the distal phalangeal joint while the finger is held in flexion; it can occur when another player's shirt is grabbed. The ring finger is affected most commonly as it is often the longest finger when the digits are flexed. There may or may not be an associated avulsion fracture (Figure 6). Operative management is required to ensure flexion of the distal interphalangeal joint is restored. This can include the use of bony anchoring devices (eg a Mitek anchor) or sutures tied externally over the finger, traditionally over a button.

Mallet finger

This injury occurs when the extensor digitorum communis tendon avulses from its insertion at the base of the distal phalanx. This can be with or without an associated avulsion fracture. It commonly results from a blow to the tip of the finger causing hyperflexion. On examination, the distal interphalangeal joint is held in a flexed position, with an inability to straighten it actively (Figure 7). Usually this injury is treated conservatively in a mallet splint for 6–8 weeks. With this, the distal interphalangeal joint is immobilised in extension or even hyperextension. If there is joint subluxation, or a large or particularly displaced dorsal avulsed fragment, then manipulation under anaesthesia may be required, along with Kirschner wire fixation (eg Ishiguro technique) or open reduction and internal fixation.

Boutonnière deformity

Damage to the central slip, overlying the proximal interphalangeal joint, can cause the lateral bands to migrate towards the volar side of the finger, leading to two unopposed actions: flexion at the proximal interphalangeal joint, and extension at the distal phalangeal joint. The clinical features are illustrated in Figure 8. The injury can be caused by avulsion, laceration or degenerative changes at the proximal interphalangeal joint, such as those caused by rheumatoid arthritis. The proximal interphalangeal joint should be splinted in full extension for 6 weeks. If there is also an avulsion fracture, surgery may be required.

Figure 7. Right middle finger mallet deformity and an example of how this may look on a lateral radiograph.

Figure 8. Right ring finger Boutonnière deformity.

'Fight bite'

This type of injury is covered in the accompanying article on hand infections (https://doi.org/10.12968/hmed.2020.0234). Direct tendon repair may have to be delayed until any infection has cleared.

History

A focused history is key when presented with a patient with a hand injury. Independent risk factors for tendon injuries include being male, aged 20–29 years, a mechanism involving glass and working as a labourer (Jong et al, 2014; Chang and Tay, 2018). Table 3 highlights important history points to ask any patient.

Examination

A full hand examination should always be performed when examining a new patient. This includes the neurovascular status of the affected hand and digit. However, the following are important with regard to tendon injuries.

Table 3. Important factors to note from the patient history

History	Important points to ascertain
Patient demographics	Age
	Hand dominance
	Occupation
	Hobbies
Date and time of injury	Adhere to British Society for Surgery of the Hand guidelines (2020b, c) regarding timing of surgery (earlier intervention usually leads to better functional outcomes)
Mechanism of injury	Open injury (eg penetrating trauma) or closed injury (eg avulsion or attrition)
	Type of implement involved (if any)
	Position of fingers at time of injury (for example, held in flexion or extension when cut as this gives an indication to the position of tendon ends)
Presenting complaint	Loss or reduction in range of movement
	Bleeding (pulsatile or venous ooze)
	Numbness (including distribution)
Past medical history	Previous trauma or surgery to the hands
	Arthritides
	Communicable disease status (hepatitis B or C, HIV)
Medication	Allergies
	Anticoagulants (can influence anaesthetic options and surgical timing)
	Vaccination status (including tetanus)
Social history	Smoking status
	Drug and/or alcohol use
	Gauge likelihood of compliance with splint, cast and/or surgery

Look

Inspect both hands together. Look at the resting position of each hand, more specifically its cascade (Figure 9). Are there any obvious abnormalities? Do any digits not flex or extend like the others?

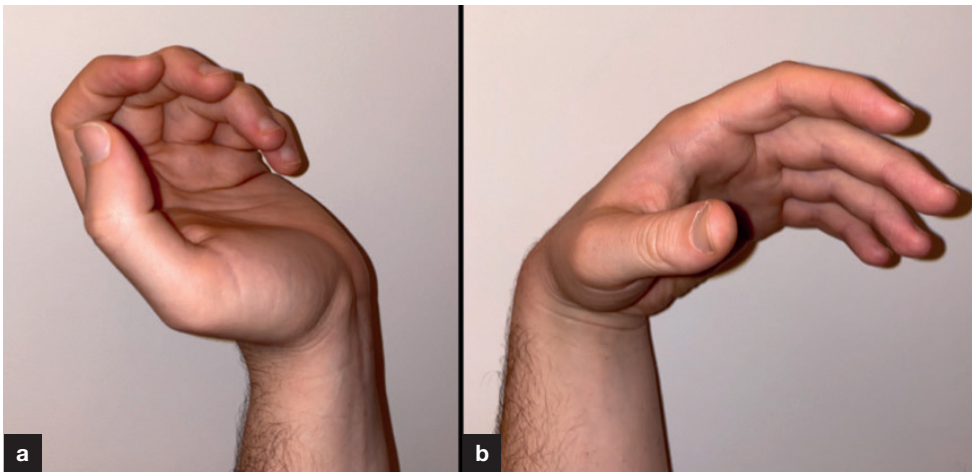

Figure 9. Normal hand cascade when the wrist is in (a) a fully extended and (b) flexed position. Note the continued arc of the fingers.

Table 4. How to specifically examine each tendon

Structure		Method	If injured
Fingers	Flexor digitorum profundus	Hold the digit in question at the level of the middle phalanx and ask the patient to just flex the distal interphalangeal joint	The respective joint may not move at all and the action may be painful. This could indicate a complete rupture. If they are able to move the joint, but it is limited, weak (after applying some resistance) or painful, this could indicate a partial rupture
	Flexor digitorum superficialis	Hold all other digits with proximal interphalangeal joint and distal interphalangeal joint s in full extension, (therefore stopping any interference from flexor digitorum profundus to the test digit) and ask the patient to flex at the respective proximal interphalangeal joint	
	Extensor digitorum communis	With the hand flat on a table, can the patient extend each digit against resistance, or is there a lag?	
	Extensor indicis proprius	With all fingers flexed, can the patient fully straighten their index finger?	
	Extensor digitorum minimi	With all fingers flexed, can the patient fully straighten their little finger?	
Thumb	Flexor pollicis longus	Hold the proximal phalanx and ask the patient to flex the interphalangeal joint	
	Extensor pollicis longus	With the hand flat on a table, can the patient lift their thumb off it?	

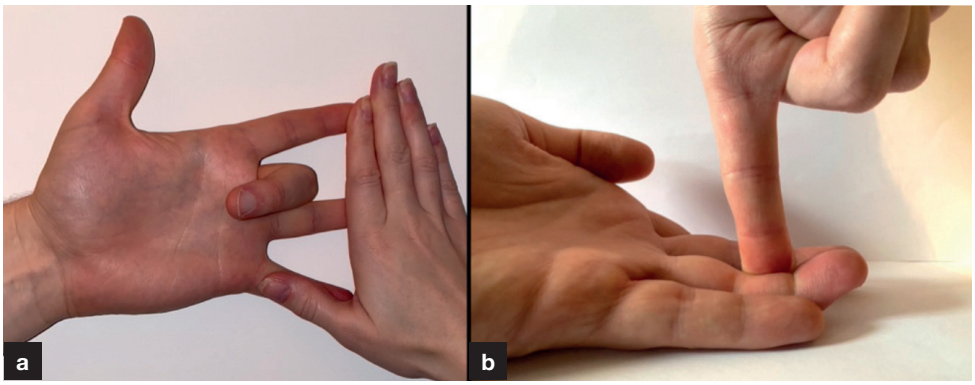

Figure 10. a. Testing the left middle finger flexor digitorum superficialis. b. Testing the left ring finger flexor digitorum profundus.

Tendons are commonly injured via lacerations and it is important to identify the zone of injury as well as any additional injured structures (eg bones, nerves and vessels). A volar laceration proximal to flexor zone 2 is most likely to first affect the flexor digitorum superficialis tendon, whereas within and distal to zone 2 the flexor digitorum profundus is most likely to be affected first. Is there any skin loss that may require a skin graft or local flap to cover exposed tendons or other structures?

Feel

Is there a palpable lump that may indicate an avulsed bony fragment or bunched end of a tendon? Is there a palpable gap in the tendon?

Move

Test each hand tendon with both active and passive movements, noting any weakness or inability to move the tested digit (Table 4 outlines each tendon's examination, and Figure 10 shows how to test the flexor digitorum profundus and flexor digitorum superficialis correctly). Figure 11 displays a flexor digitorum profundus injury to a right little finger, with Figure 12 showing a flexor digitorum superficialis and flexor digitorum profundus injury. If the patient can still move the digit, but there is weakness or pain on resistance, this may indicate a partial tendon injury. If a patient suffers a large, distal, volar laceration at the wrist, where multiple tendons, nerves and vessels are affected, they are said to have a 'spaghetti wrist' injury.

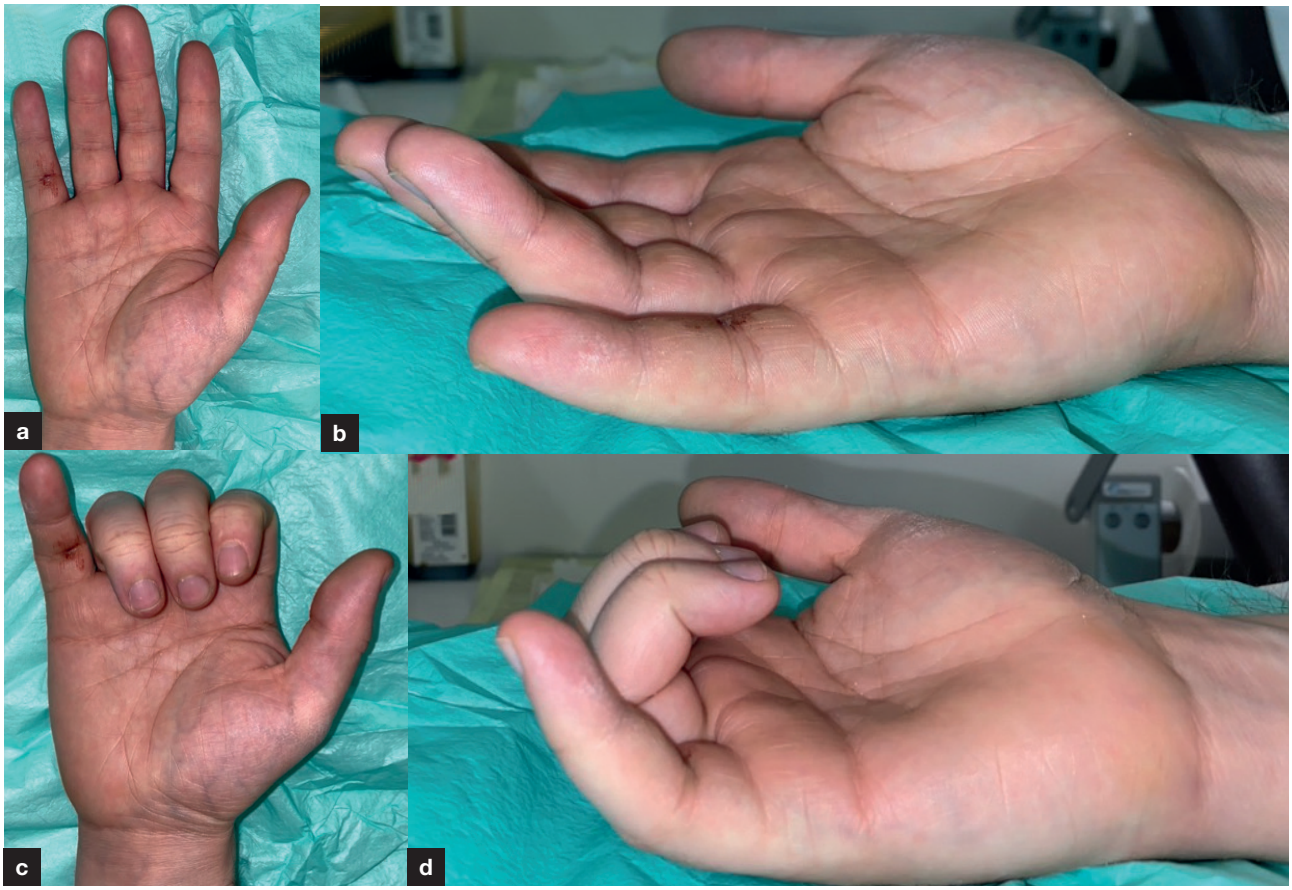

Figure 11. a. Flexor zone 2 laceration to right little finger. Note the previous middle finger injury. b. Hand cascade at rest, note the more pointed direction of the little finger. c. When asked to flex all fingers fully (anterior-posterior view). d. When asked to flex all fingers fully (lateral view)

Investigations

A radiograph is important to identify any associated bony injury, especially avulsion fractures caused by the pulling force of a tendon at its insertion. These should include posteroanterior, lateral and oblique views. The position of an avulsed fragment can help to inform where the proximal end of the tendon might be (eg caught at one of the flexor

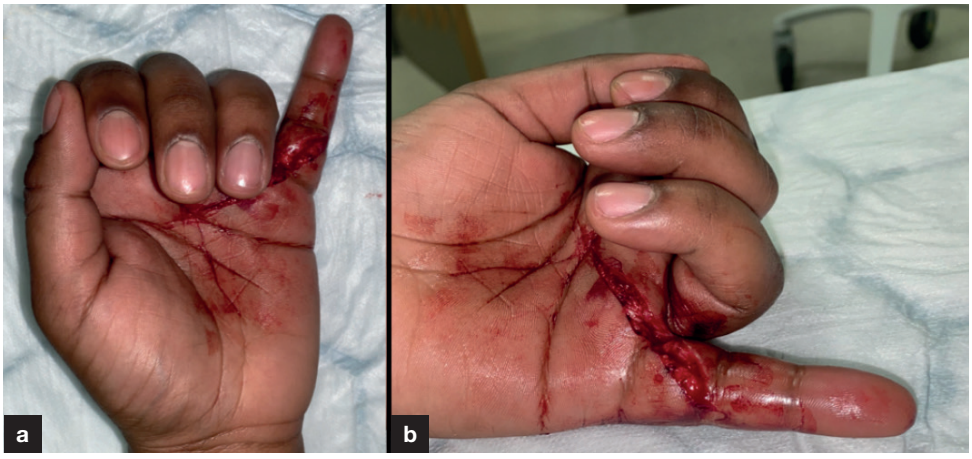

Figure 12. Flexor zone 2 laceration to right little finger and ring finger, from a knife. Both pictures during active finger flexion. Note the pointed position of the little finger. The patient had a full transection of the flexor digitorum superficialis and flexor digitorum profundus in their little finger, with a partial laceration to the flexor digitorum profundus and full transaction of the flexor digitorum superficialis in their ring finger. a. Anterior-posterior view. b. Oblique view.

pulleys). Radiographs can also identify bony shards that may impact on tendons acutely or in the future (eg a dorsally angulated metacarpal bone spike causing wear and tear of an overlying extensor tendon). Foreign bodies may also be seen – glass is radio-opaque (usually only seen if >2 mm) (Halaas, 2007) and can continue to damage tendons when in situ. Routine blood tests are often done in the emergency department, but specifically consider sending full blood count (white cell count and platelets), C-reactive protein, clotting and viral serology if indicated. An ultrasound scan may be helpful to try and identify the location of retracted proximal tendon ends or if there is uncertainty in the diagnosis (eg central slip avulsion).

Management

Emergency department

All wounds should be washed out with saline. Instillation of local anaesthetic can be helpful for pain relief and to aid proper examination of wound depth and injured structures. A photograph is useful when referring a patient and to place in their medical notes (there are now many NHS compliant apps available for smartphones). A non-adherent dressing (eg Atrauman, Mepitel, Jelonet) should be applied. If a tendon injury is suspected, a supportive splint is important to avoid further tendon damage or migration. Flexor tendon migration from a laceration in the more distal zones is less common because of the vincula attachments (the thumb does not have these, therefore retraction is more commonly seen). With the extensors, retraction of the proximal tendon end is associated with injuries at or proximal to zone 6 in the fingers or zone 4 in the thumb. Antibiotics should be commenced (eg co-amoxiclav or an alternative if the patient is allergic to penicillin) and analgesia provided. Elevation in a supportive sling is helpful to mitigate any swelling. The patient may also require a tetanus booster (and/or immunoglobulin), as well as hepatitis vaccination.

Surgical

Tendons will invariably not heal unless there is direct contact between its two ends. Intervention can often be done using either local or regional anaesthetic (eg brachial block). The technique used can depend on the zone of injury and likelihood of proximal tendon end retraction. The British Society for Surgery of the Hand advises that patients with either flexor or extensor tendon injuries should be seen by a specialist at the next available soft tissue hand clinic (ideally within 24 hours). All flexors and open extensor tendon injuries should be repaired within 4 days if they require operative management (British Society for Surgery of the Hand, 2020b).

A variety of direct repair techniques has been described for flexor and extensor tendons. Figure 13 illustrates two of the most common techniques for flexor tendon repair, including the modified Kessler (Wilhelmi, 2019) or cruciate (McLarney et al, 1999) approach. For extensor tendons a mattress or modified Kessler is often used. A ‘core’ suture is first performed within the centre of a tendon and can have a varying number of ‘strands’ or passes between the tendon ends. This is then followed by an ‘epitendinous’ suture around the circumference of the now re-opposed ends. Figure 13 shows two common techniques for this. The British Society for Surgery of the Hand (2020b) advise that a ‘suitable core suture should be selected for the size of the tendon’ and this will depend on the location of the injury. For example, in relation to flexor tendons they advocate ‘in an adult zone 2, this would be a minimum 4 strand locking configuration with at least a 3/0 calibre suture’. The use of a higher number of strands has demonstrated better tensile strength and gap resistance (Viinikainen et al, 2008). The authors’ department’s preference is to use a 4 strand core suture (eg 3/0 prolene) with a running epitendinous suture (eg 6/0 prolene, using a simple running or Silfverskiold technique). Round bodied needles should always be used. The epitendinous component helps to add 20% to the overall repair strength (Ahn and Allen, 2020) and ensures a smoother cross-section to allow better tendon glide through the pulley network. A 1 cm bite for the core suture should be taken (Tang et al, 2005).

Sometimes a tendon is not thick enough to allow a 4 strand core suture. For example, the calibre of extensor tendons significantly changes from proximal to distal. In that case, a 2 strand core suture is advised, especially when repairing extensor tendons injured in

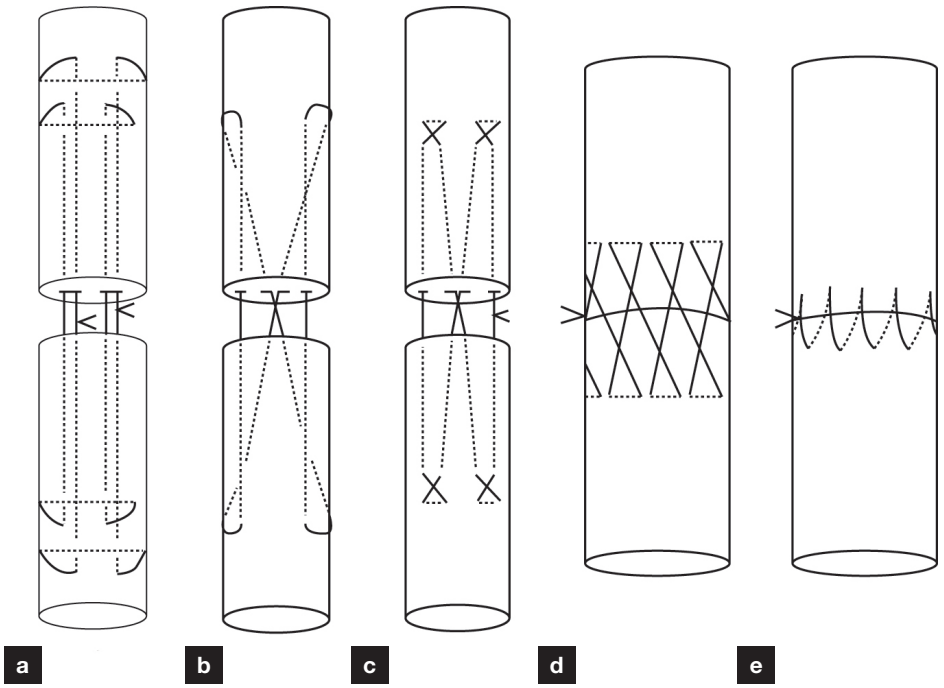

Figure 13. Examples of 4 core suture techniques used in tendon repairs (a) modified Kessler repair, (b) cruciate repair, (c) Adelaide repair) and of epitendinous suture techniques (d) Silfverskiold, (e) simple running.

the more distal zones or using a figure-of-eight suture at the musculo-tendinous junctions in the forearm.

For both flexor and extensor tendons, partial injuries can sometimes be repaired using a simple mattress suture or left to heal conservatively if <50% of the cross-sectional area is affected (Wray et al, 1977). It is important to ensure that the core suture knot is embedded within the substance of the tendon, as well as the epitendinous knot being located in a place not to impede tendon glide. If a more bulky flexor tendon repair is not able to glide effectively, one or more of the pulleys may have to be vented or divided. One should aim to preserve the annular A2 and A4 pulleys to prevent bowstringing of tendons on flexion.

If the proximal tendon end cannot be found in the vicinity of the original wound, the wound may have to be extended or exploratory wounds will have to be made more proximally along the hand or forearm. Once retrieved, the tendon can be pulled through the associated system to reach the distal tendon end. If it will not reach, then a silicone rod may have to be inserted to bridge the gap initially, and then a second stage procedure conducted to insert a tendon graft (eg harvested from the palmaris longus tendon).

Figure 14 shows intraoperative photos of the tendon repairs undertaken for the same patient pictured in Figure 12.

Splinting and rehabilitation

For flexor tendon repairs, a dorsal blocking splint should be applied postoperatively (wrist in neutral or slightly flexed, metacarpophalangeal joints flexed to 50° and interphalangeal joints fully extended; Griffin et al, 2012). For proximal extensor tendon repairs, a volar splint should be applied. The wrist, metacarpophalangeal joints and interphalangeal joints are placed in varying degrees based upon the exact site of the extensor repair. More distal extensor zone injuries may just require zimmer splinting or none at all (Griffin et al, 2012). The splints are worn at all times for a total of 4–6 weeks. Patients are then weaned to just night wearing and then nothing at all. At 8 weeks, the patient can return to light work and driving, increasing to heavy work and contact sports at 12 weeks postoperatively.

Controlled early active mobilisation within the splint is key to ensure optimal postoperative function, but also prevent tendon rupture. Specific protocols are used, guided by the patient's hand therapy team. With appropriate mobilisation, the tensile strength of the tendon increases, helping to avoid adhesions and allow improved gliding (Masson, 2003).

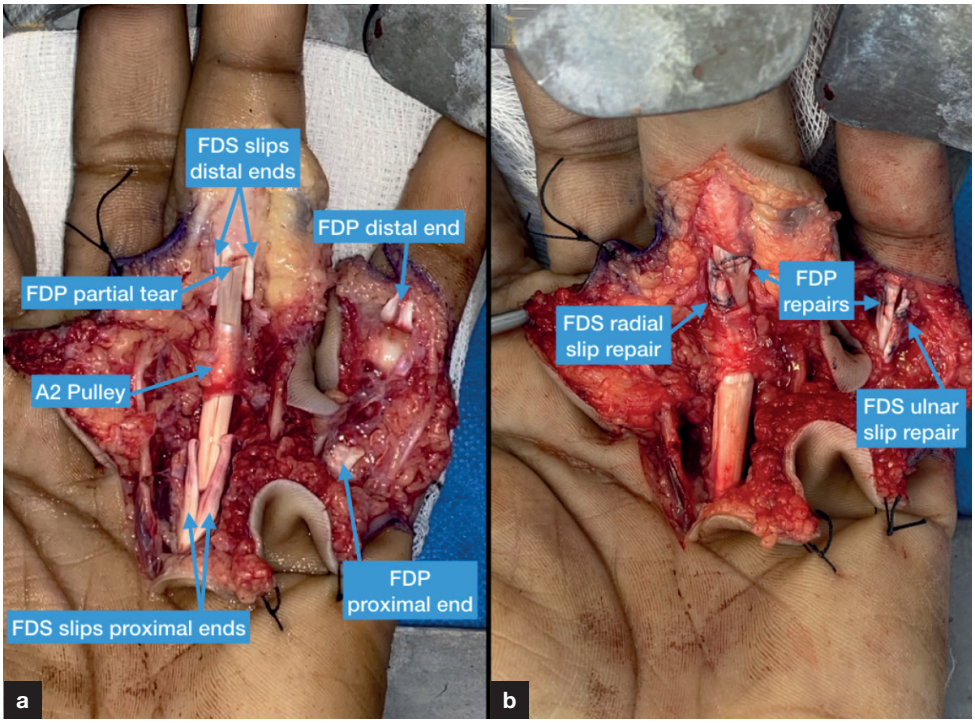

Figure 14. Intraoperative photos of the tendon repairs for the same patient in Figure 12. a. Pre-repair, b. Post-repair. FDP = flexor digitorum profundus; FDS = flexor digitorum superficialis.

Complications

The most common complications are tendon re-rupture, adhesion formation and joint stiffness. Others include infection, poor tendon gliding, scarring and complex regional pain syndrome.

The re-rupture rate has not really changed over the last 20 years, with an incidence of approximately 3–9% of cases (Elliot et al, 1994; Dy et al, 2012). Adhesions are found in 4% (Dy et al, 2012), with a higher risk if the injury was a zone 2 flexor injury. It is important that patients are informed of these potential complications when consent is obtained.

Conclusions

Presentations to emergency departments with hand injuries, specifically tendon injuries, are commonplace. The hand is an extremely complex anatomical unit and therefore healthcare professionals who will see these patients must be able to accurately examine it, instigate initial management and make appropriate referrals to dedicated hand specialists. Missed diagnoses can cause great morbidity for the patient and a complex management challenge. This article gives a guide to the key points to consider.

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Conflicts of interest

The authors declare no conflicts of interest.

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Key points

- Hand injuries are extremely common and account for a large percentage of presentations to emergency departments.
- The hand is a complex anatomical unit and needs to be examined carefully in order to identify tendon injuries.
- Missed diagnoses can cause lifelong morbidity for a patient, therefore it is crucial these are identified.
- Initial management of tendon injuries including wound washouts, photography, dressings, splints and antibiotic cover are important first steps. If being seen by emergency department staff, this should then be followed by referral to the specialist hand team.
- Operative management is often required and this should be done ideally within four days of the injury. Rehabilitation under the care of hand therapists is of paramount importance to ensure good functional outcomes.

References

Ahn L, Allen D. Flexor tendon injuries. 2020. https://www.orthobullets.com/hand/6031/flexor-tendon-injuries (accessed 25 May 2020)

British Society for Surgery of the Hand. Hand injuries. 2020a. https://www.bssh.ac.uk/patients/conditions/hand_injuries (accessed 25 May 2020)

British Society for Surgery of the Hand. Lacerations with flexor tendon involvement. 2020b. https://www.bssh.ac.uk/_userfiles/pages/files/professionals/Trauma%20standards/3%20Flexor%20tendon%20final.pdf (accessed 5 November 2020)

British Society for Surgery of the Hand. Lacerations with extensor tendon involvement. 2020c. https://www.bssh.ac.uk/_userfiles/pages/files/professionals/Trauma%20standards/4%20Extensor%20tendon%20final.pdf (accessed 5 November 2020)

Chang M, Tay S. Flexor tendon injuries and repairs: a single centre experience. J Hand Surg Asian Pac Vol. 2018;23(4):487–495. https://doi.org/10.1142/S2424835518500479

Coats R, Echevarria-Ore J, Mass D. Acute flexor tendon repairs in zone II. Hand Clin. 2005;21(2):173–179. https://doi.org/10.1016/j.hcl.2004.11.001

Dy CJ, Hernandez-Soria A, Ma Y, Roberts TR, Daluiski A. Complications after flexor tendon repair: a systematic review and meta-analysis. J Hand Surg Ams. 2012;37(3):543–551. https://doi.org/10.1016/j.jhsa.2011.11.006

Elliot D, Moiemen NS, Flemming AFS et al. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. J Hand Surg Br. 1994;19(5):607–612. https://doi.org/10.1016/0266-7681(94)90126-0

Gibson T, Schnall SB, Ashley EM, Stevanovic M. Accuracy of the preoperative examination in zone 5 wrist lacerations. Clin Orthop Relat Res. 1999;365:104–110. https://doi.org/10.1097/00003086-199908000-00014

Griffin M, Hindocha S, Jordan D et al. Management of extensor tendon injuries. Open Orthop J. 2012;6(1):36–42. https://doi.org/10.2174/1874325001206010036

Halaas G. Management of foreign bodies in the skin. Am Fam Physician. 2007;76(5):683–690

Ishak A, Rajangam A, Khajuria A. The evidence-base for the management of flexor tendon injuries of the hand: review. Ann Med Surg. 2019;48:1–6. https://doi.org/10.1016/j.amsu.2019.10.006

Jong J, Nguyen JT, Sonnema AJM, Nguyen EC, Amadio PC, Moran SL. The incidence of acute traumatic tendon injuries in the hand and wrist: a 10-year population-based study. Clin Orthop Surg. 2014;6(2):196–202. https://doi.org/10.4055/cios.2014.6.2.196

Magee DJ, Zachazewski JE, Quillen WS, Manske RC. Pathology and intervention in musculoskeletal rehabilitation. 2016. https://www.sciencedirect.com/book/9780323310727/pathology-and-intervention-in-musculoskeletal-rehabilitation (accessed 13 October 2020)

Masson J. Hand III: flexor tendons. Sel Read Plast Surg. 2003;9:1–39

McLarney E, Hoffman H, Wolfe SW et al. Biomechanical analysis of the cruciate four-strand flexor tendon repair. J Hand Surg Am. 1999;24(2):295–301. https://doi.org/10.1053/jhsu.1999.0295

Miranda BH, Spilsbury ZP, Rosala-Hallas A et al. Hand trauma: a prospective observational study reporting diagnostic concordance in emergency hand trauma which supports centralised service

improvements. J Plast Reconstr Aesthet Surg. 2016;69(10):1397–1402. https://doi.org/10.1016/j.bjps.2016.06.030

Strauch R. Extensor tendon injury. In: Wolfe S (ed). Green's operative hand surgery. 6th edn. New York: Churchill Livingstone; 2011

Tang JB, Zhang Y, Cao Y, Xie RG. Core suture purchase affects strength of tendon repairs. J Hand Surg Am. 2005;30(6):1262–1266. https://doi.org/10.1016/j.jhsa.2005.05.011

Verdan C. Half a century of flexor-tendon surgery: current status and changing philosophies. J Bone Joint Surg Am. 1972;54(3):472–491. https://doi.org/10.2106/00004623-197254030-00003

Viinikainen A, Göransson H, Ryhänen J. Primary flexor tendon repair techniques. Scand J Surg. 2008;97(4):333–340. https://doi.org/10.1177/145749690809700410

Wilhelmi BJ. Orthopedic surgery for flexor tendon lacerations treatment & management. 2019. https://emedicine.medscape.com/article/1238823-treatment#showall (accessed 25 May 2020)

Wray Jr RC, Holtman B, Weeks PM. Clinical treatment of partial tendon lacerations without suturing and with early motion. Plast Reconstr Surg. 1977;59(2):231–234