# Management of the injured hand - Principles of assessment

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## Introduction

The hand is an organ whose parts affect its entire function. Hand injury patterns are innumerable, vary widely and are a common presentation in an emergency department. The aim of this 3 part article series is to highlight the general principles that can be applied to many injuries. Assessment is based purely on a comprehensive knowledge of hand anatomy and its functional implications.

Hand injuries occur frequently in the young and the economically productive group with a male preponderance [1]. Industrial and agricultural injuries, home accidents and injuries sustained due to interpersonal violence are among the foremost causes. Even though the injury may appear trivial to the layman, in the long-term, the actual damage and functional impairment could be debilitating. While time away from work and the resulting economic loss is significant following an injury as minor as a crushed fingertip, mutilating hand injuries constitute a real challenge as many would not return to pre-injury functional status. Hence the priority is to achieve maximal hand function in the shortest possible time. In this regard, the expertise of the treating surgeon is critically important in determining the overall outcome.

A comprehensive history and meticulous hand examination based on its anatomy is the key to identifying injured structures prior to surgical exploration. It is common practice to ask the patient about the dominant hand, but in actual fact, both hands are equally important irrespective of an individual's status or occupation, as many basic human requirements are successfully fulfilled with the help of both hands. Details of the mechanism of injury are a vital factor that guides peri-operative decision making, which is also a predictor of long-term outcome. The extent of tissue damage and loss is greater in crush injury or in blast injury compared with incised injuries, hence the likelihood of poorer outcomes are significantly higher. In addition, the degree of expected contamination and timing of definitive repairs or reconstructions would depend primarily on the mechanism of injury.

The hand is often subjected to trauma, with a varying degree of damage. Meticulous assessment based on its anatomy and function is the key to successful surgical repair. Surgical exploration without methodical preoperative examination, can potentially lead to incomplete reconstruction. Repeated and delayed explorations are strongly associated with poor outcome especially in flexor tendon injuries [2].

### Assessment of tissue viability

Vascular assessment is the priority in assessing the injured hand. The extent of the vascular injury and the duration of ischaemia determine if the injured part can be salvaged. The vascular status of an injured digit is assessed by inspection of the colour, capillary refill and capillary bleeding. A vascularized finger will appear pink, with capillary refilling time of between 1 and 2 seconds. By contrast, a pale hand with delayed or no capillary refill indicates arterial insufficiency. Also, exceptionally brisk capillary refill in a finger with a dusky appearance may indicate venous congestion. Often, in industrial and agricultural injuries, the injured hands are covered with dirt, which interferes with

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vascular assessment while hand vascular assessment in individuals with dark skin and thickened skin may be inaccurate. It is important to appreciate that, even in a completely devascularized finger, stagnant blood beneath the fingernail can be moved with compression mimicking capillary refill. A reliable indicator in these doubtful situations is to assess capillary bleeding from tissue following a needle prick. Here a bright pink or red bleed indicates healthy tissue, while dark, brisk bleeding following pin-prick indicates venous congestion. Clinical assessment of distal pulse is mandatory and can be aided with a hand held Doppler instrument. Compartment syndrome is not uncommon especially following crush injuries and high suspicion of such combined with timely release of pressure is vital to maintain tissue viability. Tissues affected most by compartment syndrome are nerves and the intrinsic hand muscles [3].

**Soft tissue assessment, the nail bed and fingertip**

The skin over the dorsal aspect of the hand is lax and stretchable. The relative mobility of the dorsal skin over the extensor tendons, facilitate the movement of the joints. In the oedematous hand, this tissue layers become stiff limiting the finger flexion. The unique skin on the palmar aspect is fixed to the palmar fascia by the fibrous septa. The fibro-fatty subcutaneous layer in the palm acts as a cushion, while the fixity limit the relative mobility of the palmar skin. The extent and nature of the traumatized soft tissue is assessed carefully, with a plan for tissue replacement if there is an expected defect in the cover. In sharp cut injuries as with glass, knife or blades, there is hardly tissue loss but such injuries notoriously transect everything down to bone through a small wound in the skin. On the other hand, moving machinery or the impact of blunt objects crushing and tearing soft tissue causes mechanical destruction of tissue. Such tissue loss is further enhanced by tissue ischaemia following disruption of small blood vessels in the zone. Careful clinical observation of dermal capillary bleeding is the key to determine viability.

The tip of the finger is a unique anatomical structure and is the "eye" in the hand (Figure 1). Crush injuries involving the fingertip are relatively common in small children and young workers who handle pressing and fast moving machines. In such injuries, the nail plate is often avulsed and a distal phalanx fracture is invariably associated with nail bed injury. It is common practice to remove the partially avulsed nail in the emergency room, but this can be utilized by the reconstructing surgeon. Tissue loss is carefully analyzed as the reconstructive technique is dependent on the pattern of tissue lost [4, 5]. Crushed finger tips should not be amputated by an inexperienced operator, as the majority may be saved.

**Assessment for nerve damage**

Evaluation of injured nerves is particularly important as missed nerve injuries are not uncommon in our practice. Both sensory and motor function should be assessed prior to anaesthesia as the ends of injured nerves are not easily identified by the occasional hand surgeon - each finger receives two digital nerves which must be tested separately by using light touch. It is essential to compare the injured with the uninjured side and also to test both ulnar and radial borders of the finger separately. Questions that must be asked of the patient are; whether sensation is "normal" as in the uninjured hand or if sensation is "different to what it feels as normal in the normal hand". This step is essential as digital nerve damage may not cause absolute anaesthesia in the

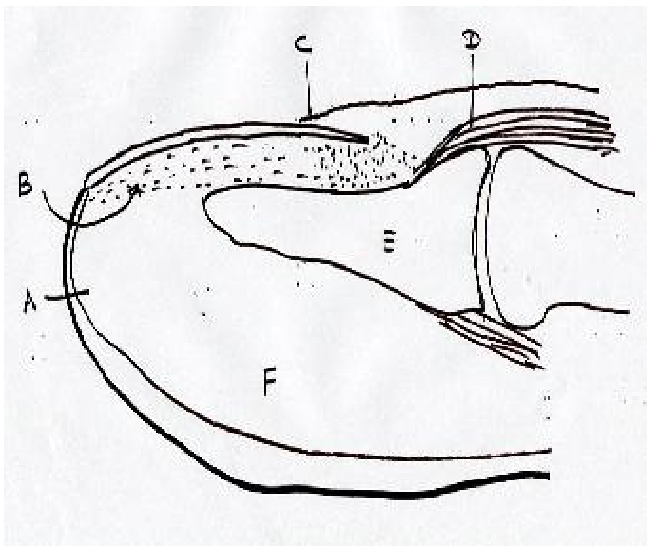


Figure 1. Anatomy of the fingertip. A. Hyponychium, B. Nail bed, C.Eponychium, D. Terminal tendon insertion, E. Distal phalanx, F. Pulp

distribution. In the case of injuries in the palm the territory supplied by the common digital nerves are evaluated. If the injury is more proximal, individual nerves must be assessed. For the median nerve, sensation of the volar aspect of thumb, index and middle fingers and for the ulnar nerve, the volar aspect of the little finger is tested. The first dorsal web space sensation should be tested for the radial nerve. Classic hand postures have been described in association with main nerve injuries, and to the experienced clinician, serve as "spot diagnoses". For example, radial nerve damage results in loss of active dorsiflexion of the wrist (wrist drop), and inability to extend the fingers and thumb (Figure 2). The classic posture of ulnar nerve damage is the 'ulnar claw hand', with hyperextension at metacarpophalangeal joint (MCPJ) and flexion of the proximal and distal interphalangeal joints (IPJ) of the ring and little fingers (Figure 3). Froment's sign indicates paralysis of adductor pollicis and the first dorsal interosseous muscles, which are supplied by the ulnar nerve (Figure 4a). The "pointing index finger", when the patient attempts to flex all the fingers is the classic posture in median nerve injury (Figure 4b). The degree of the deformity following major nerves varies depending on the level of the injury [6, 7,8].

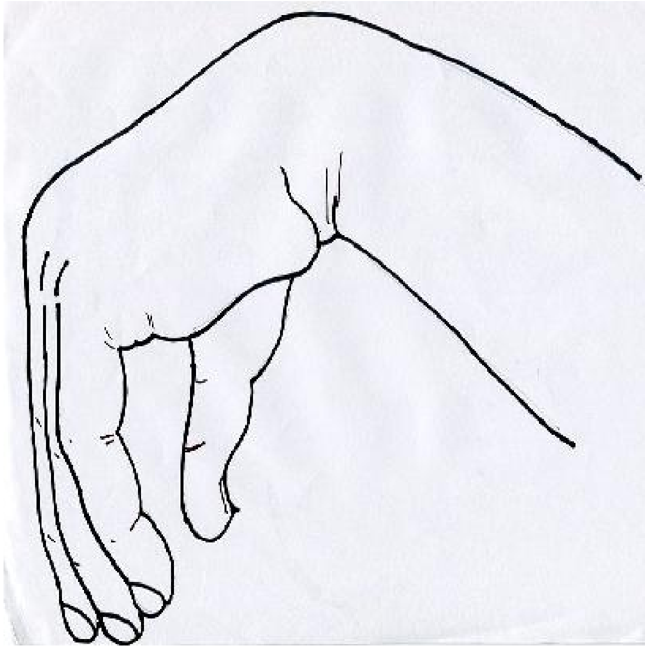

Figure 2. Wrist drop: patient is unable to actively dorsiflex at the wrist; active extension of the finger and thumb is lost.

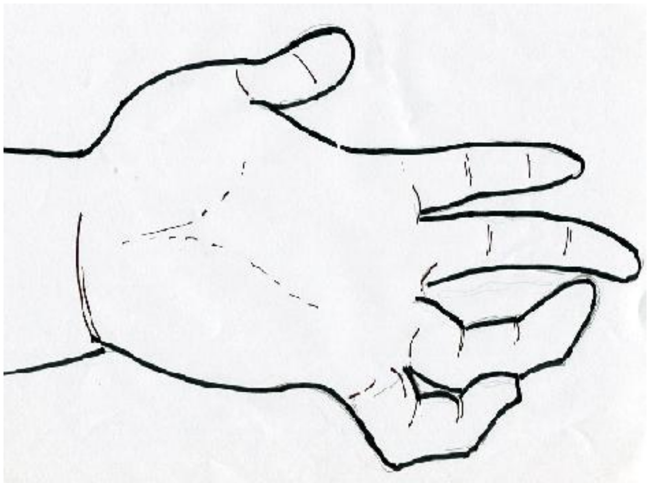

Figure 3. Ulnar claw hand with hyperextension of the metacarpophalangeal joint and flexion of the inter-phalangeal joint.

**Assessment of Tendon injury**

**Flexor tendons**

The normal cascade of the hand is lost in complete injury to tendons. Flexor tendon injury may be suspected by the appearance of the finger posture with the tenodesis effect, when flexing and extending the wrist passively. The fingers assume an extended posture with passive flexion of the wrist while passive extension at the wrist flexes the fingers. In addition, manual compression of the flexor muscle bellies in the forearm causes the fingers to flex, and disruption of the sequential finger flexion in such situations implies flexor tendon injury. These maneuvers are particularly useful in examining a patient who is unable to cooperate with an instructed tendon examination. Children and unconscious patients may be assessed in such manner with reasonable accuracy.

The diagnosis and treatment of tendon injuries require comprehensive understanding of the structure and function of tendons. Skill on the part of the treating surgeon is vital from the time of examination to the completion of rehabilitation. In the forearm, the flexor muscles are arranged in three layers. The deepest layer is formed by flexor digitorum profundus (FDP), flexor pollicis longus (FPL) and pronator quadratus. In this layer the FDP to the ring and little finger is innervated by the ulnar nerve and the rest by the anterior interosseous nerve. The flexor digitorum superficialis (FDS) forms

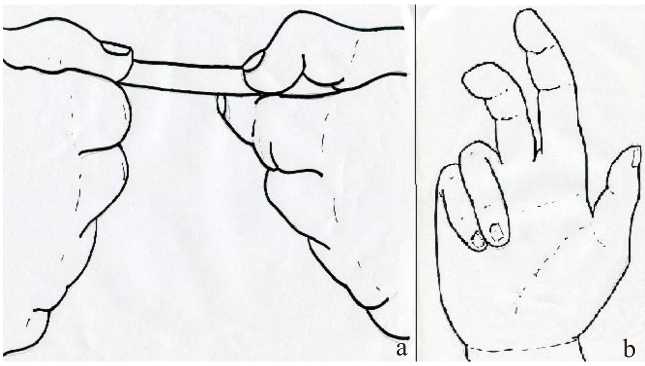


Figure 4a. Froment's sign: The patient is asked to pinch a sheet of paper between thumb and index. With paralysis of the first dorsal interosseous and adductor pollicis, significant flexion at the interphalangeal joint of the thumb results from the flexor pollicis longus action which replaces the adductor pinching.
Figure 4b. The patient is asked to flex all the fingers. With median nerve injury, the patient flexes ring and little fingers with the action of ulnar innervated flexor digitorum profundus and ulnar two lumbricals. The patient will not be able to flex the index and middle fingers. Thus, the patient displays a claw shape, where the little and ring fingers and flexed, the index and middle fingers extended.

the intermediate layer which is innervated by the median nerve which runs along its deep surface. The superficial layer consists of flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), pronator teres and palmaris longus. The FCU is innervated by ulnar nerve and the rest of the superficial layer innervation is by the median nerve.

Nine tendons of long finger flexors pass through the carpal tunnel along with the median nerve. The FPL is the radial most while all FDP tendons are posterior to the FDS. The middle and ring finger FDS tendons are superficial to the other two FDS tendons. In the finger, these tendons travel within a synovial lined fibrous flexor sheath. The pulley system in the fibrous flexor sheath is a unique anatomical structure which prevents bowstringing of the tendons. These are named annular (A 1 to A 5) and cruciate (C1 to C3) pulleys (Figure 5). The A 2 and A 4 pulleys, at the level of proximal and middle phalanges respectively, are the most important functionally. In exploring and repairing flexor tendons maximal preservation of these pulleys should be a priority. The flexor tendon is divided in to five zones for the management and academic purposes(Figure 6). Zone 1 is distal to the FDS tendon insertion and contains only the FDP tendon. Zone 2, also known as “no man's land”, starts from the A 1 pulley. Both FDP and FDS tendons lie in zone 2, which is the most crowded place in the flexor sheath. Potential for adhesion formation, preventing tendon gliding is common in zone 2. The point at which the lumbricals originate from the FDP is taken as the commencement of zone 3. Zone 4 is within the carpal tunnel. From the muscular tendon junction to the proximal carpal tunnel is zone 5. Being inserted on to the volar aspect of the distal phalanx, the FDP is the only tendon that will allow flexion of the distal inter phalangeal joint (DIPJ). In testing, the examiner should immobilize the proximal interphalangeal joint (PIPJ) in full extension, and ask the patient to flex the distal phalanx (Figure 7). All fingers in the injured hand should be examined individually. The FDS tendon inserts into the volar aspect of the middle phalanx. In testing FDS it is mandatory to block the action of common bellied FDP tendon by blocking the DIPJ flexion of 2 or 3 fingers. Accordingly, the patient is asked to flex the finger while the examiner holds the other fingers in extension(Figure 8). In the index finger the FDP muscle belly may have independent control and

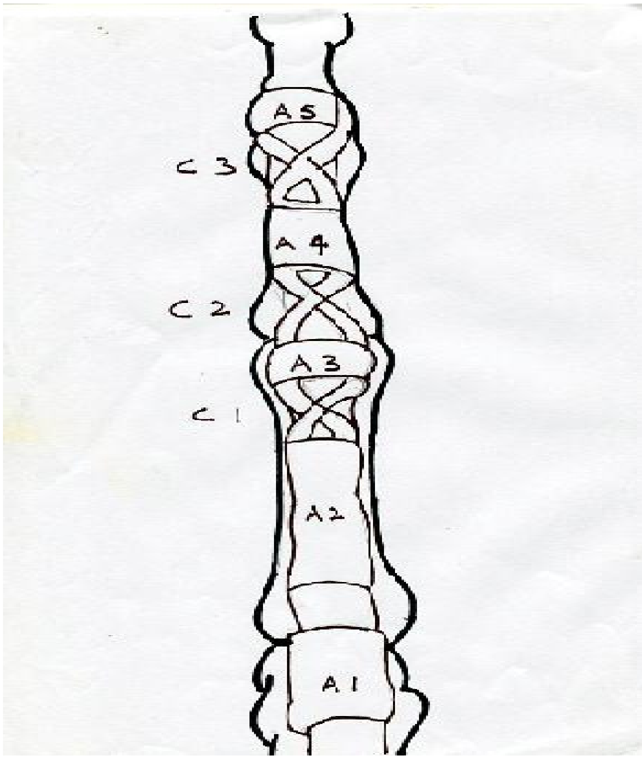


Figure 5. Fibrous flexor sheath and its condensations forming annular and cruciate pulleys.
Annular pulleys are named as A 1 to A 5. Cruciate pulleys are named as C 1 to C 3.

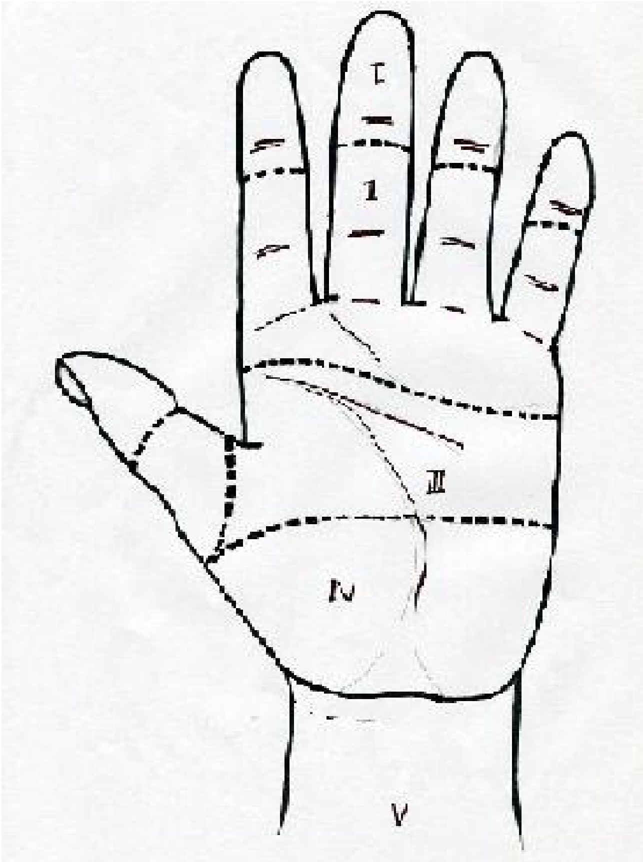


Figure 6. Flexor system is divided into five zones for descriptive purposes.

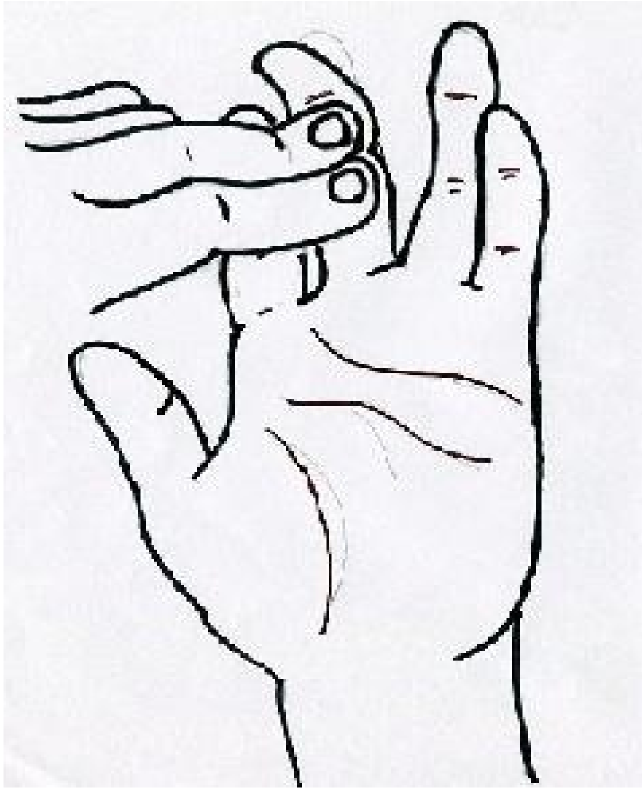

Figure 7. Testing the integrity of flexor digitorum profundus.

in this situation FDS is tested by asking the patient to press the pulp of the index finger against the pulp of the thumb. The thumb has one flexor tendon; the flexor pollicis longus (FPL), and is tested by flexing the interphalangeal joint of the thumb [9,10,11] .

**Extensor tendons**

Extensor tendons are susceptible to injuries as they lie subcutaneous in the dorsum of the hand. Even though the extensor tendons have not attracted the same degree of attention as the flexor tendons, anatomically and mechanically, they are complex structures. The post repair rehabilitation varies according to the zone of injury and delayed reconstruction is challenging especially in zone III. Extensor tendons are thin and flat over the phalanges, making the standard core suture technically impossible. The three wrist extensors; the extensor carpi radialis longus and brevis are inserted on to the bases of second and third metacarpals while the extensor carpi ulnaris tendon is inserted on to the base of fifth metacarpal. Extensor digitorum communis (EDC) provides tendons to each finger while extensor indicis proprius and extensor digiti minimi extends index and little finger respectively, the action independent of EDC. The thumb receives extensor pollicis longus which is the only extensor at the interphalangeal joint of the thumb. Extensor pollicis brevis is a muscle which cannot be tested in isolation. The radial nerve or its continuation, the posterior interosseous nerve, is the responsible motor supply of the whole group of extensor muscles [12].

Under the extensor retinaculum, these tendons are arranged in six fibrous compartments on the dorsal aspect of the wrist (Figure 9). Over the dorsum of the hand, fibrous bands called juncturae tendinae, connect the extensor tendons. The significance is that some degree of finger extension is preserved if the EDC is injured proximal to the juncturae. Sagittal bands maintain the central position of the extensor tendon over the MCPJ. Further distally, the tendon becomes a flat structure and divides into central slip and lateral bands, which receives tendons of the intrinsic hand muscles.

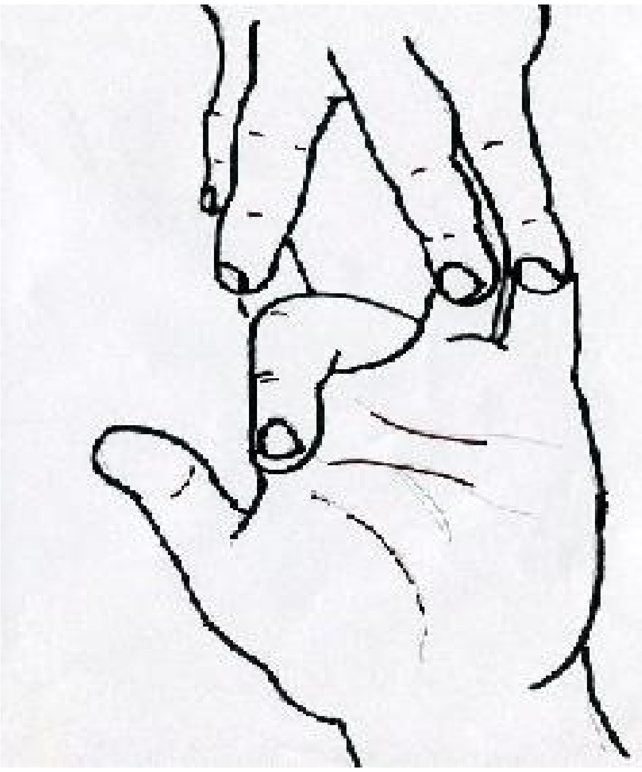

Figure 8. Testing the integrity of flexor digitorum superficialis.

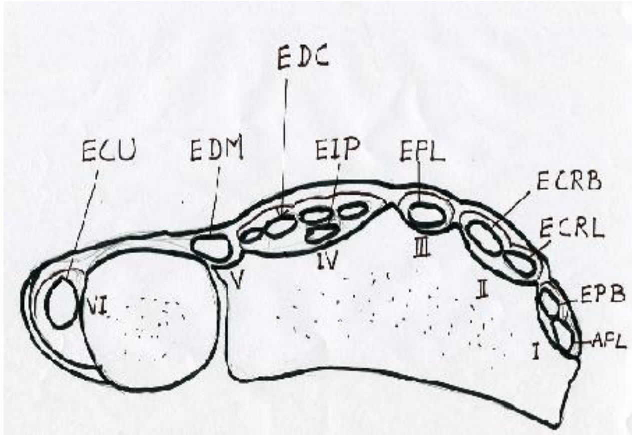


Figure 9. Extensor tendons are arranged into six compartments over the dorsum of wrist.

The terminal tendon is formed by the two lateral bands and inserts on to the base of the distal phalanx forming the extensor of the DIPJ. Thus, injury to the terminal tendon results in mallet finger. Following injury to the central slip, loss of extension at the PIPJ can occur, and the finger may develop a boutonniere deformity with time. Elson's test is reliable in testing the central slip, where the patient is asked to extend at the passively flexed PIP joint. In central slip injury, extension at the PIPJ is lost but extension is felt at the DIPJ. Extensor tendon injuries are also classified into zones from 1 to 9 [13,14, 15} (Figure 10).

**Assessment of muscular skeletal framework**

Skeletal framework and its soft tissue attachments of the digits vary from each other [16]. The thumb is responsible for about 40-50 % of the overall hand function [17]. Thenar muscles are responsible for the wide range of movements of the thumb. The ulnar two fingers are mobile and generate more force for the grip, in relation to radial two fingers which provides stability. The thenar and hypothenar muscle groups are responsible for their specialized movements. The wide range of mobility of the thumb is largely due to the action of these short but powerful muscles. The four dorsal and three palmar interossei and the four lumbricals form the intrinsic muscles of the hand. These intrinsic muscles provide tendinous contributions to the extensor expansion. The interossei control finger abduction and adduction, and flexion of the MCPJs. The lumbricals are the main extensors of the interphalangeal joints, and flex the MCPJs. Lumbricles are unique in structure, innervation and function, hence probably important in fast, alternating movements and fine-tuning digit motion [18, 19]. The function of the hand is described in terms of the grips.

Assessment of the posture or the attitude of the hand is very informative to the clinician. Obvious deformities as rotation, angulation, overriding or shortening should signify an underlying fracture, dislocation or a ligamentous injury. The likelihood of fracture being an open injury is higher as the soft tissue cover over the hand bones and joints is considerably thin. Most bones are subcutaneous. Muscle bellies are attached only to the metacarpals. Due to the superficial nature of the joints, they are at greater risk of penetrating injuries resulting in septic arthritis. Puncture wounds, particularly human and animal bites, especially on the dorsal aspects should not be neglected. Details of these skeletal injuries are assessed with plain radiographs.

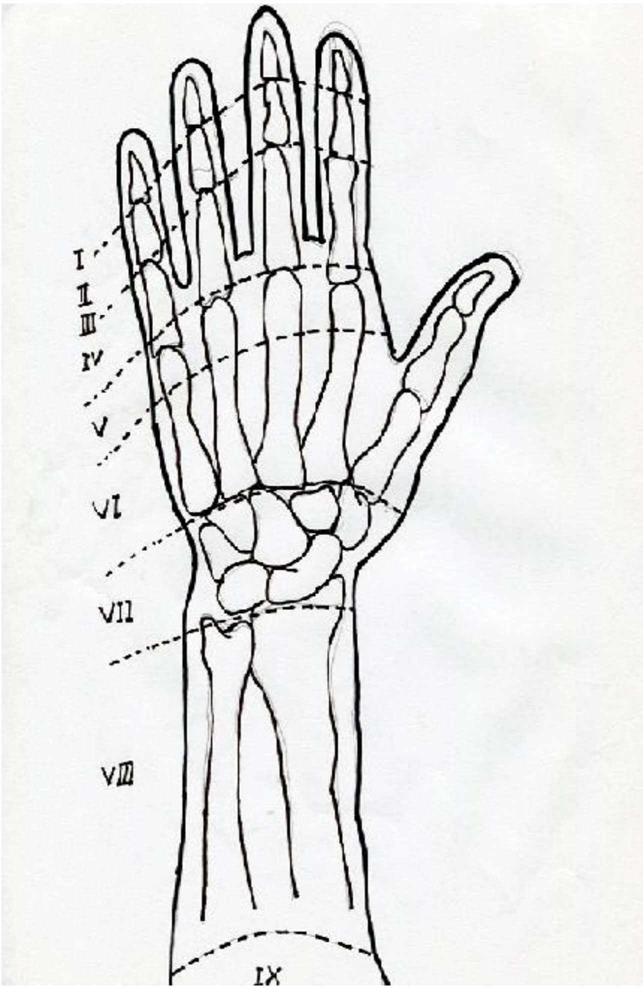


Figure 10. The extensor system is divided into nine zones.

## Initial care at the emergency unit.

Some of the movements and manoeuvres that are described above can be painful to assess. Local anaesthetic blocks are useful to alleviate pain, and should be utilized after assessing the nerves. It is mandatory to document all findings, and in the case of sensation, to map the pattern of sensory loss in a diagram. Current technology with digital photography and smart phones are useful aids in documentation and communication with a more experienced hand team. Attention to these in the emergency departments can obviate the need for repeated and painful dressing removal for the purpose of examination. If the primary treating health team is not in a position to perform an adequate initial evaluation, the hand should be covered in a loose and easily removable dressing. Acute bleeding is often the case at initial presentation - direct firm pressure and elevation is the key to achieving haemostasis in the emergency room. Application of constricting tourniquets and attempts to blindly apply haemostatic clamps must be avoided at all times as these may cause more harm.

Delayed presentations are a management challenge. Injuries with open wounds are often accompanied with tissue loss, oedema, infection and granulation tissue formation. Reconstruction of an inflamed hand is difficult and invariably leads to a poor outcome. Granulation tissue is replaced by a scar and is the enemy of the supple and moving hand. Myostatic contractions of the muscle will shorten the effective length of the musculotendinous units hindering primary repair in delayed cases. Complex injuries should ideally be managed in specialized units, to ensure restoration of useful hand function [20]. There is a significant difference between hand salvage with preserved function versus amputation or a functional deficit.

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