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Review

Phalangeal fractures of the hand

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The present review systematically describes common fractures of the phalanges with reference to the anatomy and the pertinent radiological classifications; in particular, the role of radiology in indicating prognosis, guiding treatment, and revealing subtle injuries, which may cause permanent loss of function.

Introduction

Phalangeal fractures are common injuries[1,2] that are frequently missed or underestimated,[3] potentially leading to significant impairment of function.[4] In this article, four intra-articular injury types and fractures will be discussed. Common classifications will be reviewed with their radiology, and how they can influence intervention and surgical decisions.

An understanding of the relevant anatomy is important when considering phalangeal fractures and their functional consequences. Controlled movement results from a complex, balanced interaction between extensor and flexor tendons, as well as support from bony and ligamentous structures.[5]

Anatomy

Finger extension is a complex process and a full description of its anatomy and mechanics[6] lies outside the scope of this review. Originating in the forearm, the extensor tendon of the finger passes over the metacarpophalangeal (MCP) joint and divides into three at the proximal interphalangeal (PIP) joint (Fig. 1). A central slip

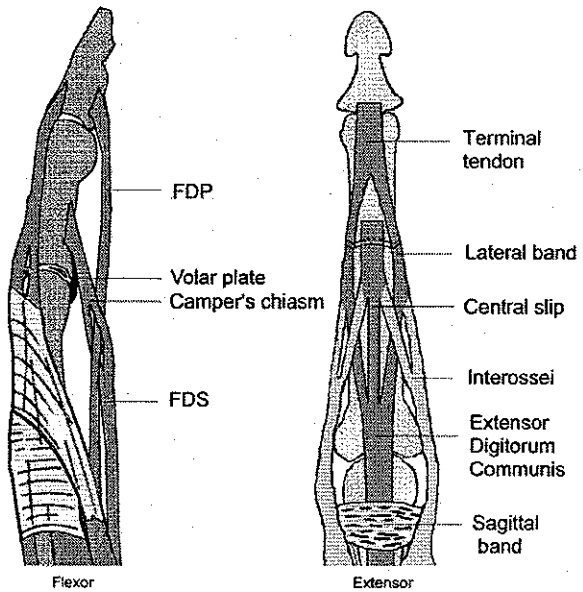

Figure 1 A simplified diagram illustrating the flexor and extensor tendon anatomy of the finger.

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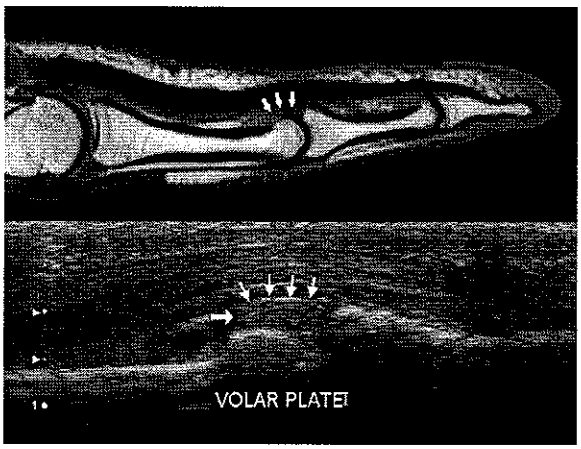

Figure 2 MRI and ultrasound images of a normal finger illustrating the location of the volar plate (arrows) at the PIP joint. The volar plate is a moderately echogenic wedge-shaped structure interposed between the flexor tendons and the PIP joint on ultrasound: on MRI it is of uniformly low signal on all sequences.

inserts into the dorsal base of the middle phalanx, and two lateral bands pass either side of the PIP joint, inserting into the dorsal base of the distal phalanx. The lumbricals and interossei are intrinsic muscles, which also insert into the lateral bands and contribute to extension.

The two tendons responsible for flexion at the DIP and PIP joint are the flexor digitorum profundus (FDP) and superficialis (FDS), which also originate in the forearm.[7] The FDS and FDP flex the PIP and MCP joints; the FDP also flexes the DIP joint. These tendons travel through the carpal tunnel, and at the level of the MCP joint, FDS lies superficial to FDP. At the level of the proximal phalanx, FDS splits into two at the chiasm, inserting into either side of base of the middle phalanx: FDP becomes superficial, running through the FDS chiasm, and inserts into the base of the distal phalanx (Fig. 1). A number of fibrous pulleys (five annular and three cruciform) restrain the flexor tendons along the length of the finger ray, keeping them close to bone and providing mechanical advantage.[8] In the event of a distal FDP avulsion from the distal phalanx, these pulleys can limit retraction of the proximal tendon end when there is a large attached bony fragment.[9] Conversely, when there is no associated bony avulsion, the tendon is free to retract proximally towards the palm.

The PIP joint is a complex hinge joint capable of the greatest range of motion in the hand.[10] Stability is provided by both bony configuration of the middle and proximal phalanges and supporting soft-tissue structures.[11] These soft-tissue structures include the collateral ligaments, the central slip of the extensor tendon, flexor tendon sheath, and the volar plate (see below). Injury to the joint and supporting structures may result in significant impairment of function.[12] The volar plate (otherwise known as the palmar plate) is a robust fibrocartilaginous structure connecting the palmar aspect of the middle and proximal phalanx (Fig. 2). Separating the joint capsule from the flexor tendons, it stabilizes the PIP joint by limiting hyperextension.[13] Distally, the collateral ligaments blend with the volar plate at its insertion into the base of the middle phalanx. Injury to the volar plate may, therefore, result in an unstable PIP joint with dorsal subluxation of the middle phalanx, especially if there is a large associated fracture at the base of the middle phalanx.[14] On ultrasound, the volar plate is seen as a wedge shaped structure of intermediate echogenicity interposed between the flexor tendons and underlying IP joint. Best seen in the sagittal plane, it is of low signal on all magnetic resonance imaging (MRI) sequences (Fig. 2).

Figure 3 Initial radiographs (left and middle) of the hand shows a fifth metacarpal neck fracture (arrows). However, the volar plate fracture was missed (circle) as no true lateral was performed. The radiograph on the right, 4 months later, shows subluxation of the PIP joint with malunion.

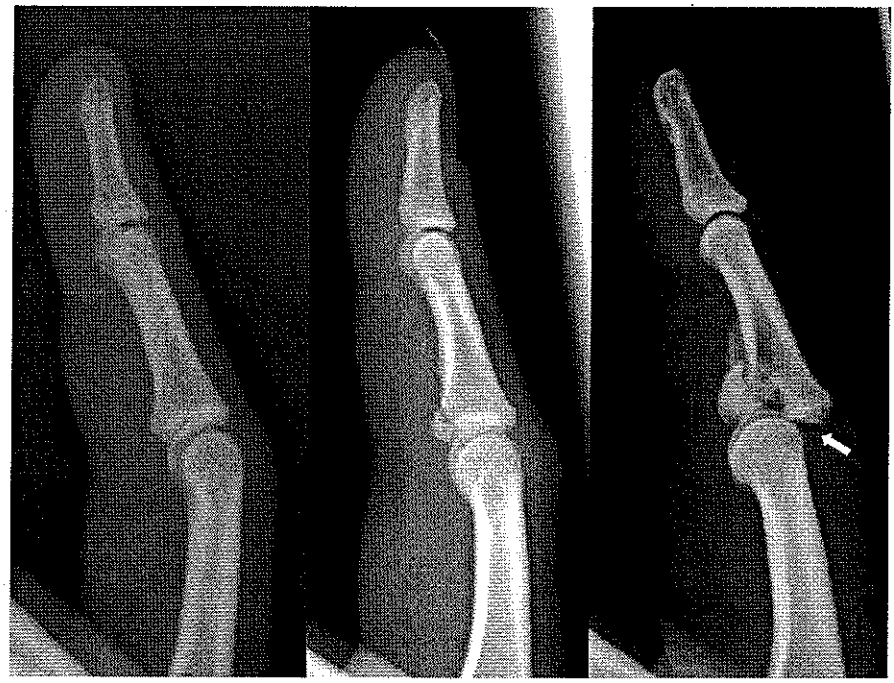

Figure 4 Three images demonstrating the grading of volar plate fractures. (a) Subtle small avulsion; (b) 25% joint surface involvement without subluxation (Eaton type IIIa); (c) 50% joint surface involvement with dorsal subluxation (Eaton type IIIb). A white arrow demonstrates the characteristic 'V' sign.

As injury to many of the above structures results in bony injuries in the sagittal plane, a true lateral radiograph, in addition to a quality anteroposterior (AP) view is essential in the initial assessment of these injuries on plain film. Oblique views are useful when further clarification is required of possible injuries.

Volar plate avulsion fracture

Forced hyperextension at the PIP joint, with or without a dorsal dislocation, may damage the volar plate. There may or may not be an associated intra-articular fracture. An avulsion fracture usually manifests as a fracture at the distal attachment at the base of middle phalanx.[15] Quality plain radiographs are the mainstay for both initial assessment and subsequent follow-up of this injury. When deciding between conservative or surgical treatment, a true lateral radiograph of the injured finger is an essential tool.[16] Furthermore, without this true lateral, volar plate injuries are easily overlooked (Fig. 3).

Table 1
Eaton classification of volar plate injuries.

Type 1	No fracture or dislocation
Type 2	Dorsal dislocation without fracture
Type 3 stable	Fracture-dislocation with <40% PIP joint surface
Type 3 unstable	Fracture-dislocation with >40% PIP joint surface

Radiographic appearances are very variable, ranging from a miniscule "spot" of bone at the volar aspect of the PIP joint to a displaced fracture involving more than half the articular surface (Fig. 4). Critically, a subluxed PIP joint results in a poor functional outcome if missed and the appearances are frequently subtle[15] (see below). Eaton[14] produced a useful classification of volar plate injuries, divided into three categories (Table 1):[17] type I is a volar plate injury without a fracture, type II a dorsal dislocation without a fracture, and type III a fracture with an associated dorsal subluxation.

With more articular surface involvement in a volar plate fracture, the balance is shifted towards operative intervention as the joint becomes increasingly unstable.[15] A small fracture may be treated conservatively as it is intrinsically stable.[18,19] When the fracture involves over 30–50% of the volar articular surface, the stabilizing collateral ligaments are attached to the avulsed volar fragment of bone, resulting in joint instability from dorsal subluxation of the middle phalanx.[20] Eaton subdivided this type III into "stable" fractures involving less than 40% of the joint surface and "unstable" fractures involving more than 40%.[14,17] Residual subluxation may be seen as a "V" sign on a lateral radiograph[21] (Fig. 4) and is associated with a poor prognosis.[15] We would therefore recommend that a surgical opinion is sought when this sign is present with the relevant clinical history. Inadequate treatment may result in disabling stiffness and pain through early degenerative change (Fig. 5).[16]

Figure 5 An Eaton type IIIb unstable volar plate fracture (a and c). The patient did not have any treatment and a malunited deformed joint is demonstrated 6 months later (b and d).

Mallet fracture

Mallet finger is the most frequently seen closed tendon injury in sports.[22] A forced flexion of the DIP joint with the finger in extension may disrupt the terminal extensor mechanism, either as a tendinous injury or a bony avulsion fracture, resulting in a loss of active extension.[23] There is unopposed flexion from the FDP, resulting in a "dropped finger".

As with closed mallet injuries without associated fracture, the vast majority of mallet fractures do not need surgical intervention, and may be treated with splinting in extension.[24] The treatment of mallet fractures with a significant intra-articular component remains controversial.[24,25]

Doyle classified Mallet injuries into four types (Table 2): type I corresponding to a closed injury with or without a fracture; type II a laceration; type III a deep abrasion with soft tissue loss; type IVa representing a transepiphyseal plate fracture in a child; type IVb a fracture involving 20–50% of the articular surface; and type IVc greater than 50% with volar subluxation of the distal phalanx[26] (Fig. 6).

Table 2
Doyle classification of mallet injuries.

Type 1	Closed injury +/- fracture
Type 2	Laceration
Type 3	Deep abrasion, soft tissue/tendon loss
Type 4a	Paediatric transepiphyseal fracture
Type 4b	Fracture with 20-50% DIP joint surface
Type 4c	Fracture with >50% DIP joint surface

Fractures that involve over a third of the articular surface of the DIP joint or result in significant volar subluxation are often treated non-surgically, but are sometimes treated with operative reduction and fixation.[23] There remains conflicting opinions about the most appropriate treatment for these type IVb and IVc fractures.[25] Mallet finger can lead in the long term to an imbalance between flexion and extension forces leading to hyperextension of the PIP joint and a "swan-neck" deformity.[23,27] There is a lack of strong evidence regarding the benefit of operative intervention even with large fracture-subluxations.[28]

Condylar fractures of the proximal phalanx

As with other PIP joint injuries, the severity of this uncommon, intra-articular fracture is often underestimated.[3] Condylar fractures of the head of the proximal phalanx are typically the result of axial loading, commonly from attempting to catch a sports ball.[29] There are established fracture patterns at the proximal phalanx condyle which may influence prognosis and management.

London[30] described three types: a type I stable, undisplaced unicondylar fracture; a type II unstable, displaced unicondylar; and a type III comminuted bicondylar fracture (Table 3, Fig. 7). Weiss[29] expanded on this intuitive, but one-dimensional, sagittal classification by describing patterns of fracture in the coronal plane. In particular, he noted that a displaced volar fragment is often associated with a poor prognosis (Fig. 8).[29] Surgery is usually indicated if there is any displacement or comminution, i.e., in London types II and III.[31] Type II is noted to be significantly more unstable due to a rotatory component that frequently displaces with conservative treatment.

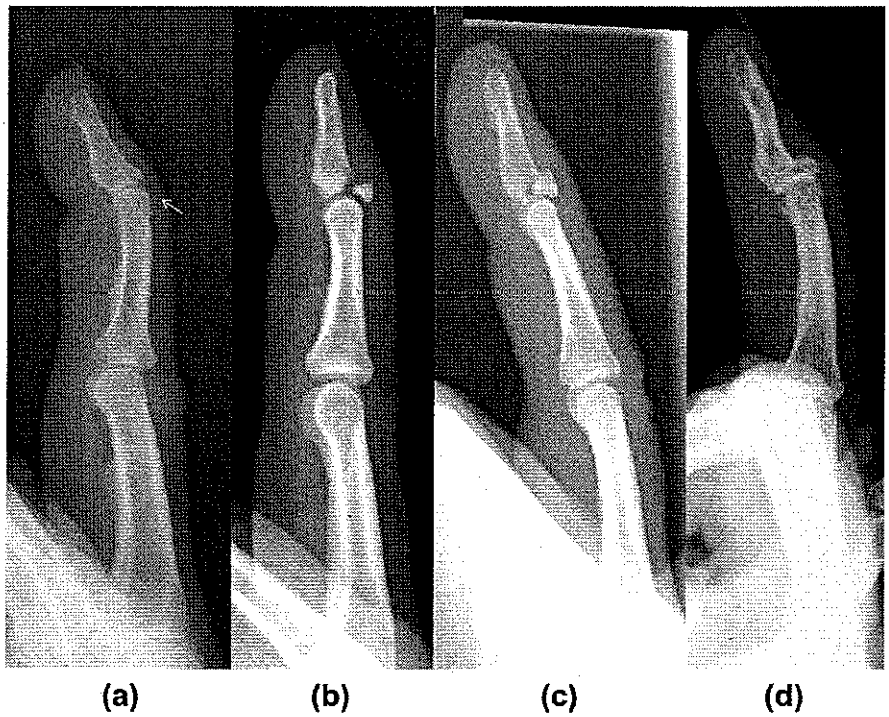

Figure 6 Mallet fractures. (a) A subtle fracture is indicated (arrow); (b) fracture with 30% joint surface involvement; (c) fracture with over 50% joint involvement; (d) an untreated mallet fracture with volar subluxation.

Type I may be treated conservatively, but with frequent radiographs to check for displacement.[31] Nevertheless, conservative or delayed treatment often results in disruption of the articular surface, early osteoarthritis, and persistent lateral angulation[31] (Fig. 8). We would therefore recommend surgical referral for all proximal phalanx condyle fractures, irrespective of the extent of comminution or displacement.

Computed tomography can provide additional information through multiplane reformats, which may preoperatively assist the surgeon in planning his approach to restoring joint congruity (Fig. 9).

FDP avulsion fracture of the distal phalanx

Injury through a forced hyperextension of an actively flexed finger can result in avulsion of the FDP, most commonly affecting the ring finger.[9,32] Known as "rugger jersey finger", a typical history is of a sudden pulling or jerking action.[33,34] Clinically, it manifests as a straight, extended DIP joint with an inability to flex the digit.

Table 3
London classification of phalangeal condylar fractures.

Type 1	Unicondylar, undisplaced, stable
Type 2	Unicondylar, displaced, unstable
Type 3	Bicondylar, comminuted, unstable

In this injury, the plain film appearance is variable. These differences reflect the FDP tendon either avulsing a fragment of bone from the distal phalanx or directly rupturing from its insertion. Leddy[9] divided FDP avulsions into three types based on the extent of proximal retraction of tendon

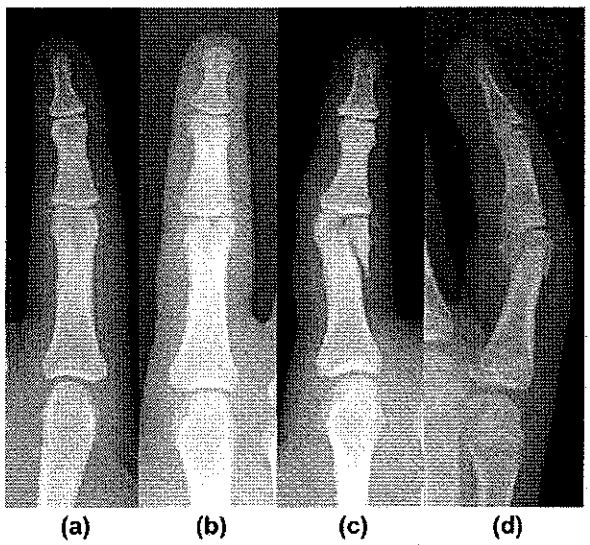

Figure 7 Condylar fractures. (a) An undisplaced unicondylar (type I); (b) a displaced unicondylar (type II); (c and d) two displaced bicondylar fractures (d is best demonstrated with an oblique view).

Figure 8 (a and b) Demonstrate two views of a condylar fracture with a volar fragment on the same patient. The AP view is relatively subtle emphasizing the importance of the true lateral. (c) Shows a malunited angulated old condylar fracture.

towards the palm (Table 4). Type I is retraction into the palm without a fracture, type II retraction to the PIP joint sometimes with a small avulsion fracture, and type III a large avulsion fracture with a small amount of retraction towards the A4 pulley at the mid-portion of the middle phalanx (Fig. 10). Irrespective of the type or mechanism, these injuries require surgery to restore flexion at the DIP joint. There is no role for conservative treatment of acute FDP avulsion.[35]

Table 4
Leddy classification of FDP avulsion injuries.

Type 1	No fracture, FDP retracts to palm
Type 2	Small avulsion fracture, FDP retracts to PIP joint
Type 3	Large avulsion fracture, FDP retracts small amount

Although this classification may indicate prognosis and assist the surgeon with planning his approach to repairing the injured digit, it may not reliably identify the location of the proximal tendon end.[36] Type II injuries may have no associated fracture.[9] The FDP tendon may further separate from an avulsed fragment of bone, migrating proximally, or may migrate less than expected.[36] In equivocal cases or when there is a delayed presentation, ultrasound is a dynamic, non-invasive adjunct to plain film, which frequently assists in locating the tendon end (Fig. 11).[37,38] MRI can be as informative,[39,40] although potentially less accessible and cost-effective, and it is not dynamic.

As well as resulting in a loss of active flexion at the DIP joint, a missed injury may result in collapse of the pulley system, with resultant scarring and reduced tendon excursion, complicating surgical reconstruction. Primary repair thus frequently fails with delayed diagnosis. In order to restore pulley integrity, staged intervention with a temporary silicon rod is often required (Fig. 12).[41]

Figure 9 CT scan of a condylar fracture, coronal reformat (arrow).

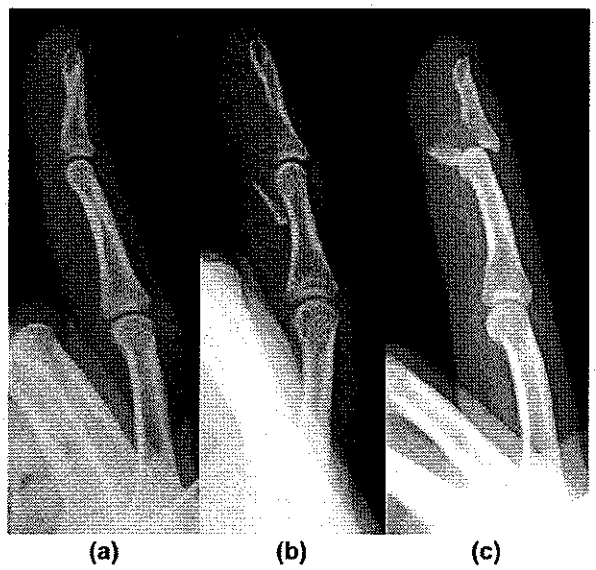

Figure 10 FDP avulsion fractures. (a) Type I injury without a fracture and a normal plain radiograph. (b) A significant fragment of bone is restrained by the A4 pulley (type III injury). (c) A large fracture with very little retraction (type III).

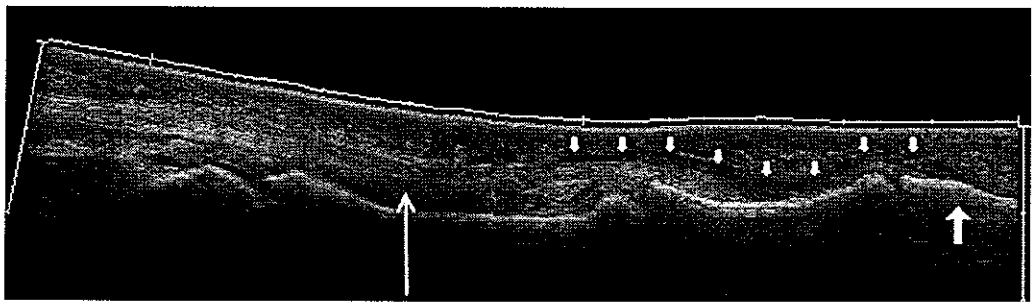

Figure 11 Panoramic ultrasound view of a closed FDP avulsion fracture. The small white arrows demonstrate the empty flexor sheath. The large arrow on the right indicates the level of the FDP insertion at the distal phalanx. The long arrow on the left demonstrates the level of the retracted FDP tendon, with associated haematoma around the proximal phalanx shaft.

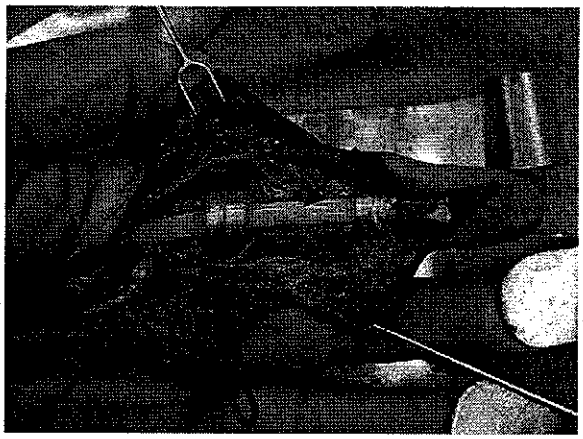

Figure 12 Intraoperative photograph of the first stage of a flexor tendon and pulley (A2 and A4) reconstruction using a silicon rod (black arrow), and autografts at the proximal and middle phalangeal level.

Conclusion

We have reviewed the radiological appearances of several frequently seen phalangeal injuries that may be overlooked or underestimated, and their relationship with functional outcome. Knowledge of the patterns of fracture in both common and uncommon phalangeal injuries is important in ensuring patients are treated in an appropriate and timely fashion. It has been shown that classifications pertaining to these injuries can sometimes be useful in assessing prognosis and surgical options. In particular, a true lateral is essential in all finger injuries and close inspection of the PIP joint is required for subtle subluxation. The use of techniques other than plain film radiography can serve as an adjunct to planning definite treatment or obtaining further information.

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