34 Metatarsal and Phalangeal Fractures

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Metatarsal Fracture

Metatarsal fractures are relatively common and are mostly caused by direct crushing injuries to the foot, inversion-avulsion injuries, and overuse injuries. Neglected injuries can cause prolonged disability [1–3].

Anatomical Consideration

Simple fractures usually have minimal displacement. This is due to the strong ligamentous attachments of the metatarsal bones to each other at both the base and near the metatarsophalangeal (MTP) joints [1]. For fracture displacement to occur, extensive damage occurs to the interossei, lumbricals, and distal intermetatarsal ligament. Appropriate distribution of weight is important to overall foot mechanics, and malunited fractures may lead to increased forces in the foot, causing metatarsalgia, localised intractable plantar keratosis, and interdigital neuroma [4].

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Radiographic Evaluation

Metatarsal shaft fractures are visualized on routine AP, oblique, and lateral radiographs of the foot. A CT scan may be necessary to evaluate the TMT joints. Most metatarsal shaft fractures are oblique or transverse. Displacement is usually minimal unless more than one metatarsal is fractured. Various fracture patterns due to displacement are shown in Figs. 34.1, 34.2, and 34.3. Fracture position is best assessed using two views that lie at a 90° angle to each other. However, overlying shadows on the lateral view often make it difficult to see metatarsal fractures. Oblique or modified lateral views are often more helpful.

Preoperative Evaluation and Indications of Surgical Management

Associated neurologic deficit, compartment syndrome, open fracture, skin devitalised or at risk for devitalisation (severe crush or shearing injuries), or vascular compromise needs prompt surgery. First metatarsal fracture (unless fracture is completely nondisplaced), more than 3 mm dorsal or plantar displacement of multiple metatarsal fracture or dorsal/plantar angulation exceeding 10°, intra-articular fracture, associated Lisfranc ligament injury, and tenderness over Lisfranc

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Fig. 34.1 Displaced lesser metatarsal shaft fracture

Fig. 34.2 Compound comminuted first metatarsal shaft fracture

Fig. 34.3 Open crush injury with associated first metatarsal fracture and dislocation (arrow)

ligament are injury factors which determine the need of reduction [2, 5].

Preferred Method of Treatment

The authors recommend that nondisplaced metatarsal neck fractures be treated conservatively with a wooden-soled shoe or short boot and progressive weight bearing, as tolerated over time. When the head is displaced plantarly, closed reduction may be attempted. The authors recommend percutaneous fixation with retrograde K-wires to maintain the reduction because these will frequently redisplace. Closed reduction is often unsuccessful, and the surgeon should be prepared to proceed with open reduction and antegrade–retrograde pinning.

Malalignment of the second, third, and fourth metatarsals in the frontal plane (medial to lateral) can usually be treated conservatively. Displacement of any metatarsal fracture in the sagittal plane (dorsal to plantar), however, should be evaluated more closely. More dorsal angulation of the fracture leads to increased plantar prominence of the metatarsal head [6]. Consequently, the distal fracture may have a higher chance of requiring surgery. Closed reduction is frequently unsuccessful because of soft-tissue swelling and interposition.

Metatarsal K-Wire Fixation: Surgical Tip and Tricks

Percutaneous Fixation

Percutaneous fixation may be considered with K-wires inserted through the plantar foot and advanced across the fracture under fluoroscopic imaging (Fig. 34.4a, b).

After preparing the metatarsal fracture site for an open reduction (Fig. 34.5a, b), a Kirschner wire (KW) which has one sharp and one blunt end is used for intramedullary fixation. It is best introduced free hand in an antegrade fashion from the fracture into the medullary canal of its distal segment. Introducing the KW by the free-hand technique allows more sensitive palpation of the fracture site. Advancing the KW in the canal helps to achieve the desired location with extensive fluoroscopy use. Intraoperative images are necessary to confirm the correct location of the KW. Once the correct position of the KW within the canal of the distal fragment is confirmed, the distal part is pushed against the head and helps to bring the metatarsus into length. At times, especially when the fracture is not fresh, significant force is necessary to overcome the shortening. In such a case, two manoeuvres can be done: After mounting the KW on a drill, the drill and the KW are pushed forcibly without rotating the KW. In this way a pushing force rather than a drilling one is applied manually. If more distraction force is needed, the toe can be grabbed from both sides at the proximal phalanx with a small Weber clamp or a towel clamp and pulled. However, the advantage of directly pushing on the head in terms of less harm to the toe is obvious. Once the desired possible length has been achieved, the KW is drilled through the metatarsal head into the base of the proximal phalanx of the toe with its sharp edge exiting from the sole (Fig. 34.5c).

Fig. 34.4 C-arm position for metatarsal K-wire surgery—foot pressed flat on the image intensifier housing of the C-arm for both positional and maximal ankle dorsiflexion views

We recommend keeping the metatarsophalangeal joint in a slight plantarflexed position, as this joint not infrequently ends up in dorsal subluxation due to scarring that occurs to the dorsal elements and the extensor tendons as a result of the injury. The drill is disengaged from the proximal part of the KW and is assembled on its distal part in the sole of the foot (Fig. 34.5d).

The wire is pulled to the level of the fracture (Fig. 34.5e). Open or closed reduction of the fracture is achieved by pushing the proximal part of the KW into the proximal intramedullary canal (Fig. 34.5f, g). If done in a closed fashion, fluoroscopy is used to assess the position of the KW within the canal in two planes. The KW is drilled further within the metatarsal medullary canal until it stops at the metatarsal base which exerts increased resistance on the dull proximal end of the KW (Fig. 34.5h).

Gentle but forceful pushing with the drill rotating and at the same time pulling on the toe will return some additional length. Although the KW has a blunt edge that stops at the base of the metatarsus, forceful pushing of the running drill may cause penetration if osteoporotic bone is involved. The wire end protruding from the sole is cut and bent, leaving a small edge for future removal.

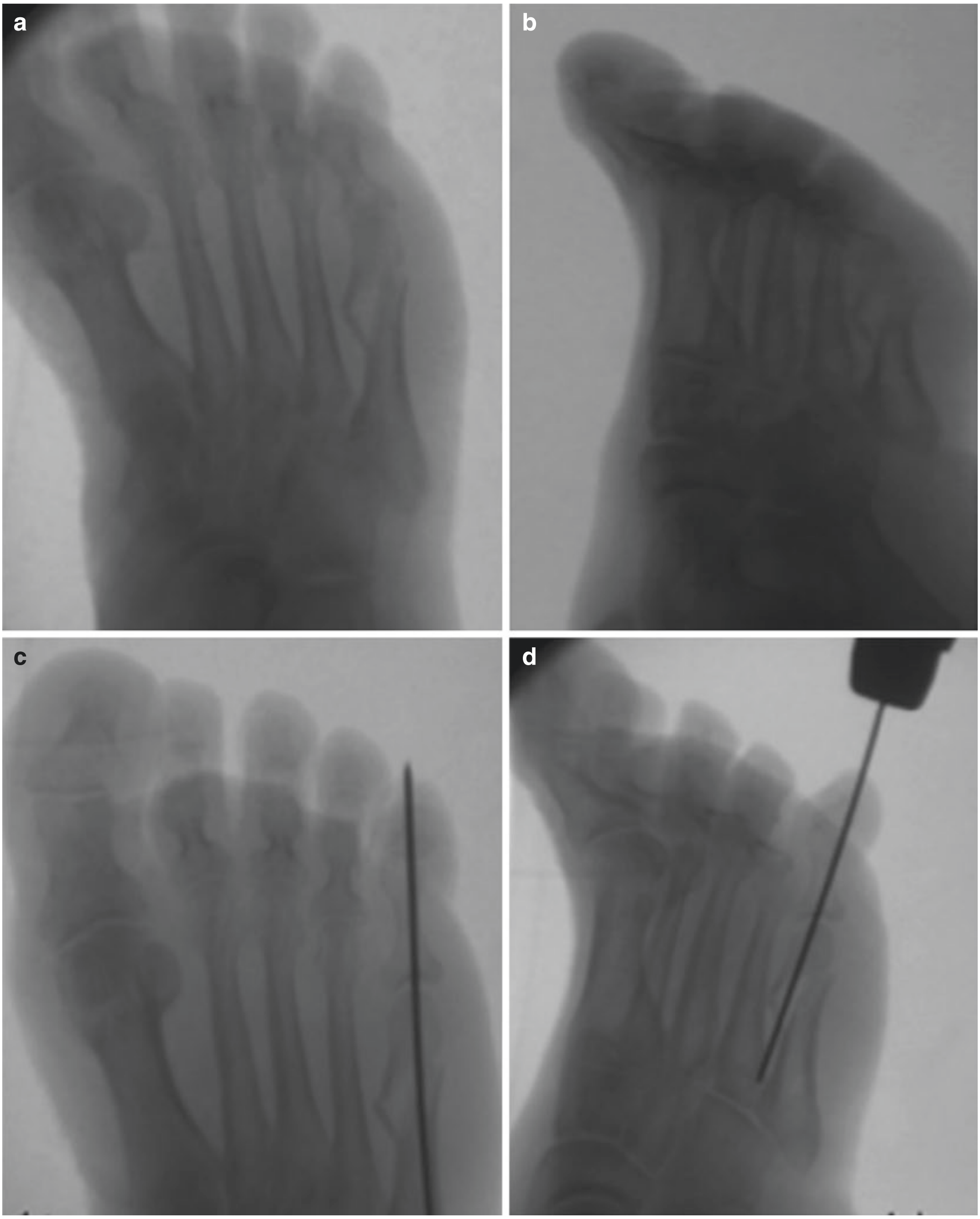

Fig. 34.5 (**a**–**h**) Denotes c-arm imaging of procedure for open reduction and internal fixation of metatarsal fracture using kwire

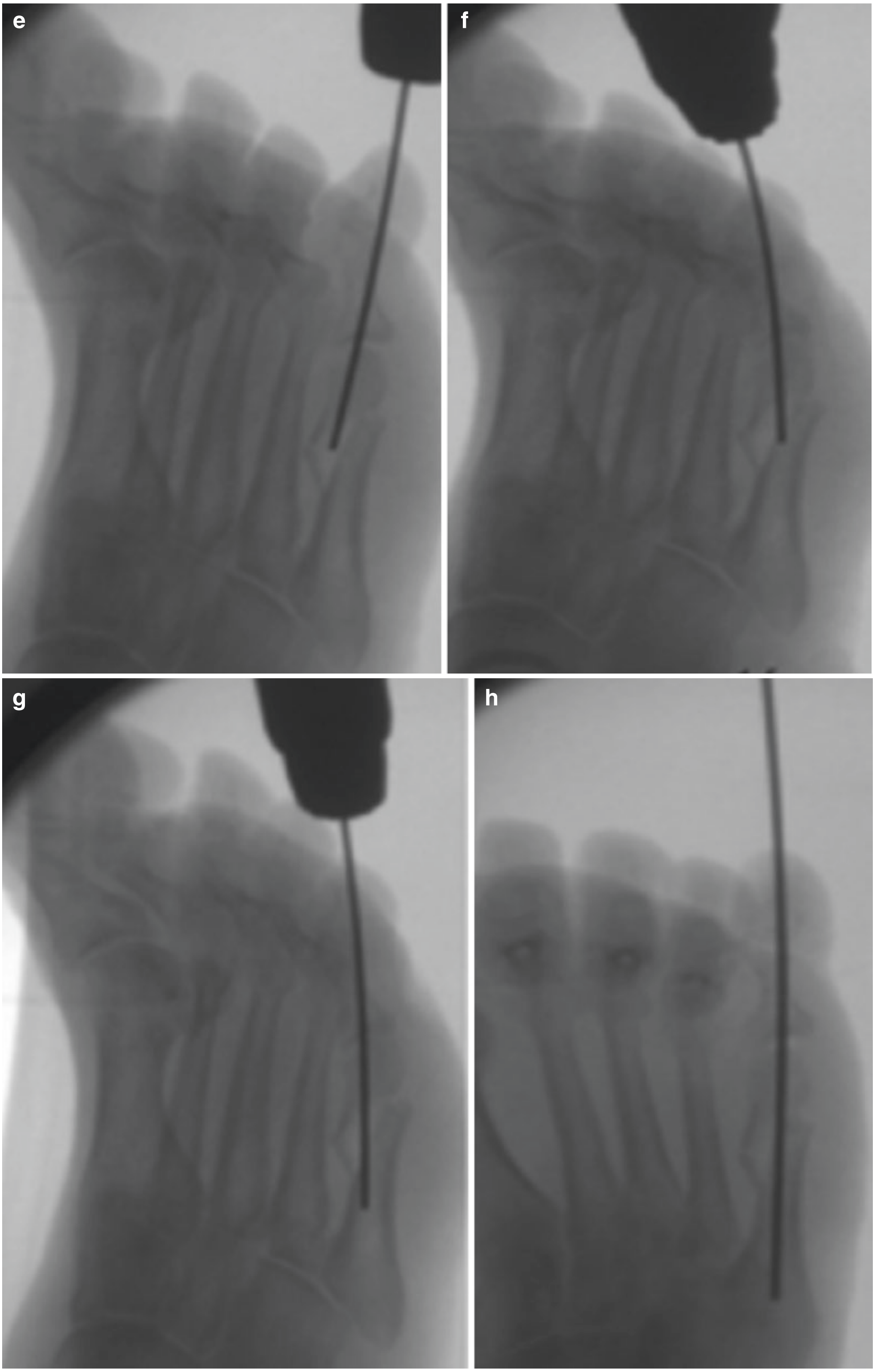

Fig. 34.5 (continued)

Heim and Pfeiffer Method

Alternatively, a small dorsal incision may allow the use of a Freer elevator to manipulate the fragments, followed by wire placement. When that manipulation is unsuccessful, open reduction is required through a formal dorsal approach, with more than one longitudinal incision necessary if the second, third, and fourth metatarsals are all involved [1, 7]. Pinning can also be performed according to the method advocated by Heim and Pfeiffer (Figs. 34.6 and 34.7). This is accomplished first in an antegrade manner through the shaft of the distal fragment and exiting the metatarsal head at the plantar aspect, followed by reduction and retrograde insertion of the pin into the proximal shaft. As stated, gross displacement may be identified by skin tenting.

If this K-wire method is unable to obtain a satisfactory reduction, then standard plating is an option. Standard plating is an option rather than K-wires. Severely comminuted fractures require either plating or cross-pinning to adjacent and more stable metatarsals. Plating is the preferred option for vertically displaced first metatarsal fracture (Fig. 34.8a–c).

Sagittal angulation is more of a concern than shortening. If unacceptable residual shortening becomes problematic, lengthening by using either distraction with subsequent grafting or distraction osteogenesis, that is, the Ilizarov technique, can be performed with acceptable results [8, 9].

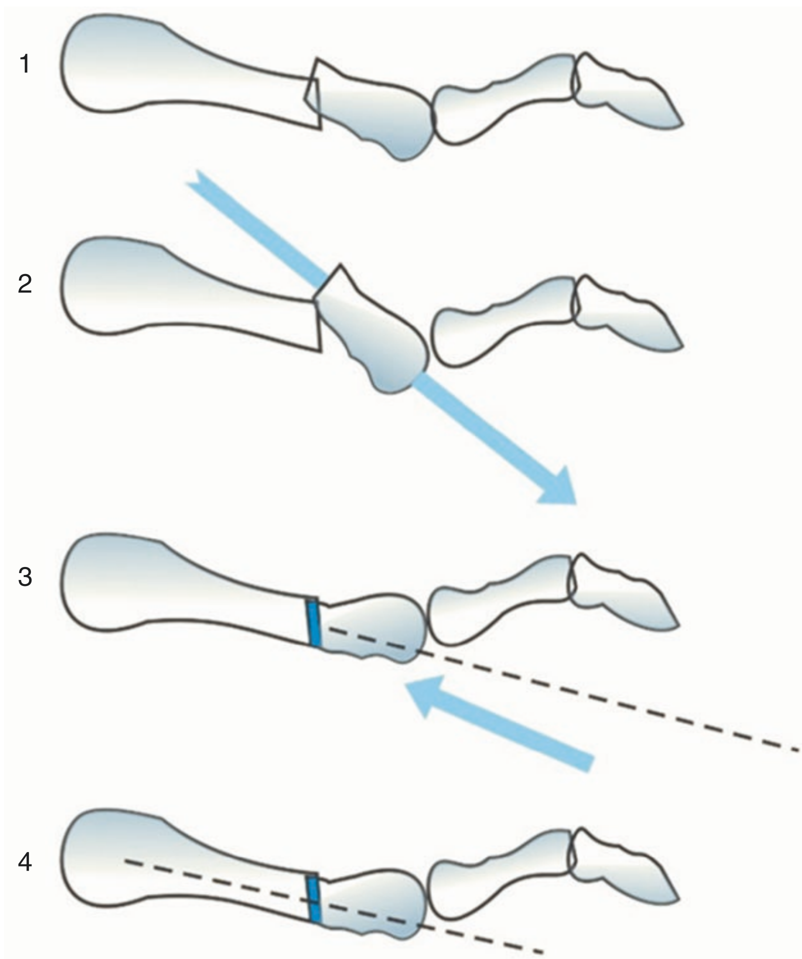

Fig. 34.6 A1–A4, sequential pinning technique for metatarsal shaft fractures

Fig. 34.7 Preoperative and postoperative radiograph of metatarsal neck fracture. K-wire fixation done by Heim and Pfeiffer principle

It is important to restore the length and the alignment of the bone anatomically in both the sagittal and transverse planes, in order to maintain normal weight bearing through the first ray. Displacement, shortening, or angulation of the first metatarsal in any plane anywhere along the bone can significantly alter the weight-bearing distribution of the foot, and is therefore an indication for operative management.

Compound Metatarsal Fracture Management

Open fractures more commonly occur from direct or crushing blows [7]. Standard open fracture management, with initial irrigation and debridement with appropriate antibiotic coverage, is indicated. Axial K-wire fixation is performed more routinely in open fractures of the metatarsal shafts to provide soft-tissue stability for healing. External fixation, however, may be required for severe degloving and crush injuries [4]. In the appropriate setting, internal fixation is acceptable. Free muscle flap may be needed according to wound condition [10].

A case example of surgical management of compound metatarsal injury is discussed in Fig. 34.9.

A 69-year-old gentleman was referred for crush injury on right foot from a local hospital where he had received initial treatment in the form of debridement and K-wire fixation (Fig. 34.9a, b). He was admitted and investigated and underwent the following in single setting—removal of K-wires, surgical debridement

Fig. 34.8 Fracture of first metatarsal shaft showing vertical displacement of the metatarsal head, suggesting that some of the soft-tissue connections were intact between the first and second metatarsal heads (**a**). Open reduction was performed through a medial incision, with a lag screw and neutralization plate (**b**, **c**)

Fig. 34.8 (continued)

Fig. 34.9 Compound metatarsals fracture with significant soft tissue injury managed by k wire fixation and flap procedures

Fig. 34.9 (continued)

(Fig. 34.9c), reapplication of K-wires (Fig. 34.9d), exploration of anterior tibial vessels, gracilis muscle flap harvest, and end-to-side anastomosis of artery and end-to-end anastomosis for vein (Fig. 34.9e, f). Patient came on follow-up after 2 months with good healing and fairly well foot function (Fig. 34.9g, h).

Fractures of the Fifth Metatarsal

The joint between the bases of the fourth and fifth metatarsals is a key landmark for classifying proximal fifth metatarsal fractures (Fig. 34.10a):

1. Tuberosity (zone 1) fractures always occur proximal to this joint and extend in metatarso-cuboid joint (Fig. 34.10b, c).
2. Acute fractures of the metaphyseal-diaphyseal junction (Jones fractures, zone 2) extend toward this joint.
3. Diaphyseal stress fractures usually occur distal to this joint (zone 3), although stress fractures also can occur in the Jones location.

Jones fractures are often confused with and must be distinguished from adjacent fractures of the fifth metatarsal. Jones fracture is positioned

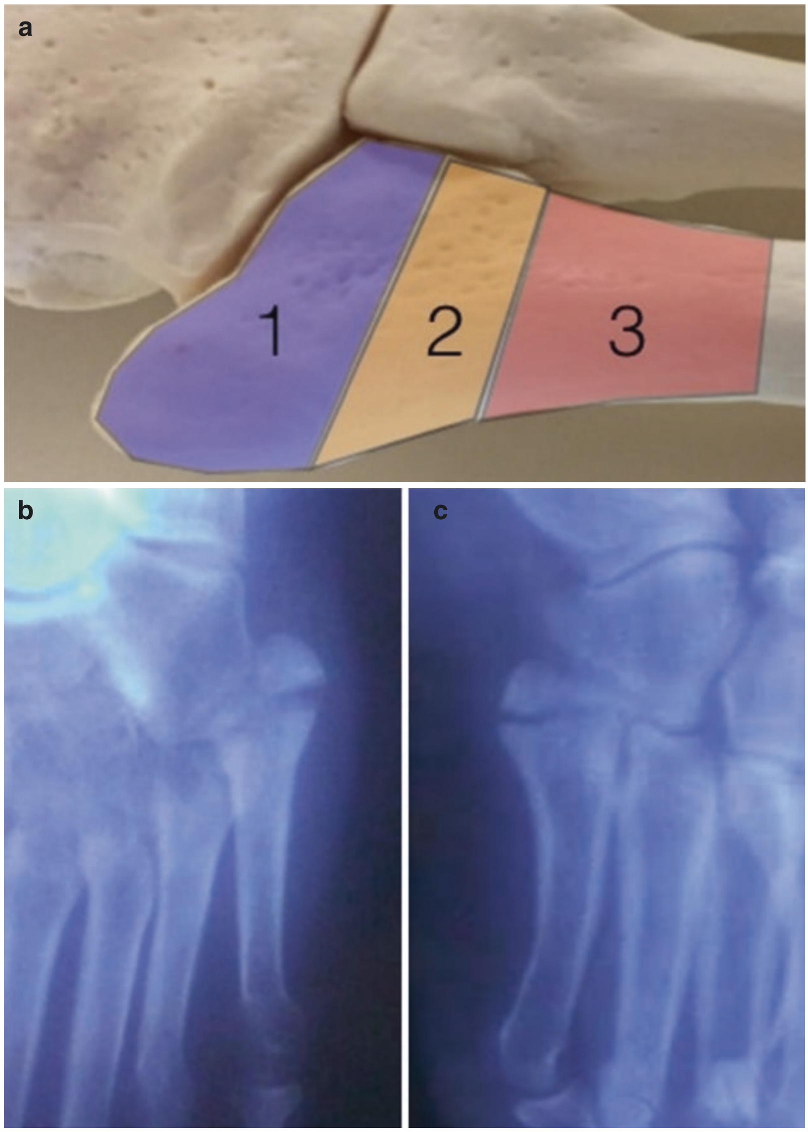

Fig. 34.10 (**a**) Classification system of fifth metatarsal fractures described by anatomic location. (**b**, **c**) Tuberosity (zone 1) fractures always occur proximal to this joint and extend in metatarsocuboid joint

between feeding vessels entering at the base of the metatarsal and the nutrient artery flowing into the diaphysis, which puts it at a greater risk for a delayed union or a nonunion. The tenuous blood supply surrounding the fracture site as well as the complex bony anatomy and curvature of the intramedullary canal all contribute to the difficulty in managing such fractures. Tuberosity fractures heal well, Jones fractures heal less well, and diaphyseal stress fractures heal poorly.

Indications and Contraindications of Surgery

Conservative management is the mainstay of treatment for the general nonathletic patients who sustain an acute Jones fracture. Since long back, a well-moulded non-weight-bearing cast is advocated for a period of 6 weeks, followed by a weight-bearing cast or boot for an additional 4–6 weeks [4]. Acute surgical intervention in the form of intramedullary screw fixation has become a popular treatment in attempts to expedite healing, decrease time back to work or sport, minimise surgical exposure, and minimise the risk of a nonunion. Patients with diabetes are still candidates for fixation provided that they have good vascular supply and protective sensation to extremities. There is an increasing consensus that supports offering surgery to young active patients, or those who are interested in returning to recreational activity or sport at an earlier time period. Another relative indication for intramedullary screw fixation includes patients with a cavovarus hindfoot alignment or lateral column overload, who are more prone to a nonunion or are felt to be more susceptible to recurrent fractures [11].

Contraindications for intramedullary fixation of a Jones fracture are few but include infection, vascular insufficiency, and significant other medical comorbidities that take precedence over treating the fracture surgically. Smoking cessation should be obligatory for the best potential outcome, but is not feasible in the acute situation.

Preoperative Planning

Preoperative planning involves a thorough history and physical examination. The examiner should ask the patient about prodromal symptoms, such as pain or swelling prior to an inciting event. Perform and document a neurovascular examination by testing capillary refill/pulses and sensation and immediately address any deficit. It is also helpful to establish whether a subacute fracture exists, by inquiring about a recent change in training or increase in activity. On physical examination, point tenderness over the base of the fifth metatarsal as well as bone percussion may reproduce the pain.

The surgeon must be astutely aware of any biomechanical abnormality, such as a subtle cavus hindfoot, which may predispose the patient to further stress along the lateral border of the midfoot and compromise the surgical results if not recognised [2]. This can be the underlying factor that increases the propensity of a nonunion or refracture, and must be addressed at the time of surgery. A vascular examination needs to be performed to confirm adequate blood supply to the foot [12]. Standing AP, oblique, and lateral radiographs are crucial in planning for a surgical intervention. Assessing the fracture location, gapping or displacement, and amount of sclerosis all help determine whether this is a delayed union or nonunion, rather than an acute fracture. This may impact the surgical management and determine whether the surgeon elects to open the fracture site, and/or bone graft the fracture, as a part of the surgery [5, 13].

Intraoperative Position and Surgical Technique (Fig. 34.11)

Pearls and Pitfalls

1. *Starting point (entry)*. Appropriate position of the guidewire is important to facilitate the proper position of the screw and avoid pitfalls such as intraoperative fracture, cortical perforation, and malalignment of the screw. The starting point ("high and inside" that means dorsal and medial) is critical. This position attempts to avoid the above-mentioned potential intraoperative complications. Another helpful hint is to hug the cuboid and take your time during this portion of the procedure. The tendency is to start the guidewire too low and superficial (lateral), which risks perforation of the medial cortex and intraoperative fracture, due to the inherent curvature and anatomy of the fifth metatarsal. Furthermore, a screw that is placed too far "outside" or lateral risks being prominent and subsequently painful (Fig. 34.12).
2. *Guidewire position*. Do not advance the guidewire too far distally in the medullary canal. The guidewire should not extend past the central portion of the metatarsal shaft. The bow of the distal canal should not be reached with the wire, nor should an attempt be made to bypass the curvature. This will risk breakage of the tip in the canal, especially when reaming.
3. *Reaming*. Reaming should be undertaken with caution to avoid complications. With correct

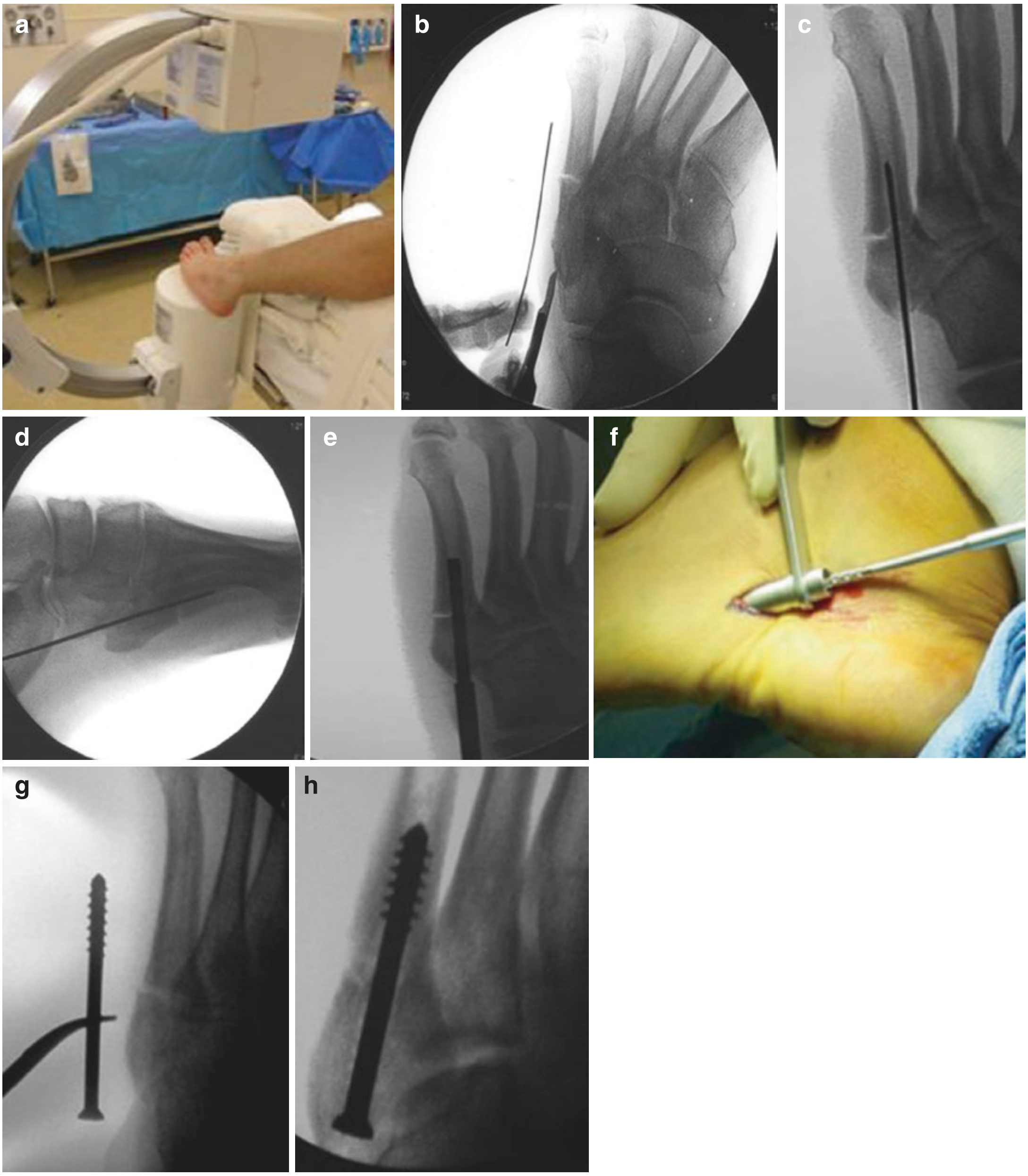

Fig. 34.11 (**a**) Patient is kept in supine position with the leg internally rotated using the fluoroscopy unit as table, to allow easy access for three views of the foot (AP, oblique, and lateral). (**b–d**) An incision is made just proximal to the base of the fifth metatarsal base. Care must be taken to avoid/protect the sural nerve, which will be located near the incision. The position of entry with guidewire must remain dorsal and medial (commonly referred to as "high and inside") to avoid perforation of the canal and to best follow the trajectory of the curved metatarsal. (**e**, **f**) A cannulated drill is used to ream over the guidewire so as to access the intramedullary canal. The wire and drill are left well short of the distal curve of the metatarsal to avoid drilling across the wire itself. It has been found helpful to then use a 3.2 mm solid drill bit to "ream" the remainder of the canal. This can be done on reverse mode, and under live fluoroscopy, avoiding cortical perforation and eccentric reaming while optimizing the entry size. The drill bit should be centrally positioned within the canal in all three views. Soft-tissue protection is a must to avoid the adjacent sural nerve and peroneal tendons. (**g**, **h**) Fluoroscopic imaging allows for confirmation of the screw length (place a screw along the lateral aspect of the foot). The screw (at least 4.4 mm) threads must cross the fracture site to obtain compression, but should not extend distally into the diaphysis, which may lead to fracture gapping and diastasis. A screw of excessive length may attempt to straighten a naturally curved bone, which can lead to fracture displacement or gapping

Fig. 34.12 Oblique radiograph demonstrating small screw used with a lateral starting position creating medial stress riser

positioning of the guidewire, cannulated reaming will direct the screw appropriately. Occasionally, in circumstances of nonunion or refracture where endosteal scalloping or irregularity is noted, reaming can be done by partially pulling the guidewire back. The drill is then directed and advanced freehand to better position the final seating of the screw. This is done with extreme caution and under live fluoroscopy. The screw will end up where you ream, so this should always be evaluated under the AP, oblique, and lateral views. If the reaming is done eccentrically, the screw will end up in an eccentric position, so take care to position the guidewire appropriately and ream accordingly.

4. *Bone grafting*. Not all authors support the use of bone graft in treating these fractures but in revision situations, nonunions with diastasis, or sclerosis, open preparation of the bone ends with associated bone grafting is often the preferred technique. Autologous local bone graft may be harvested from the calcaneus or the proximal tibia. Iliac crest bone graft is generally thought of as the standard of care in revision situations, but this does add to the morbidity of the procedure. Less invasive techniques have begun to come into favour, which allow for less morbidity but still use the iliac crest as the preferred location for the graft.
5. *Screw length*. A common mistake is to use an inappropriate screw length. The screw has to be long enough so the threads cross the fracture site in order for compression to occur, but should not extend substantially farther down the canal. With the bowed shape of the metatarsal, too long a screw will risk a distal iatrogenic fracture or will end up distracting the fracture.

Phalangeal Fractures

Proximal Phalanx Fracture

Anatomy

Phalangeal fractures are the most common fracture of the forefoot [14–16]. The proximal phalanx of the hallux is most commonly fractured. Fractures of the proximal phalanx can range from simple fracture patterns to complex with significant comminution. Because of the role of the first toe in normal gait, deformity in the first toe may be less well tolerated than in the other digits. The flexor hallucis brevis muscles can act to plantar flex a proximal phalanx fracture. This will lead to a painful prominence on the bottom of the toe, a painful plantar keratosis. Fractures of the lesser toes are more common through the proximal phalanx. Flexor and extensor tendons insert at the proximal portions of the middle and distal phalanges. These tendons may avulse small fragments of bone from the phalanges; they also can be injured when a toe is fractured. Abductor, interosseus, and adductor muscles insert at the proximal aspects of each proximal phalanx. The pull of these muscles occasionally exacerbates fracture displacement [13]. The middle and distal phalanges are smaller and less commonly fractured. The more common fracture patterns are seen in Figs. 34.13 and 34.14.

Proximal phalanx fracture of fifth metatarsal is rare, but may cause significant deformity particularly in children [17].

Fig. 34.13 Various fractures of the proximal phalanx of the hallux. (**a**) Nondisplaced shaft with articular involvement. (**b**) T-type fracture of head. (**c**) Displaced neck fracture. (**d**) Displaced shaft fracture. (**e**) Highly comminuted fracture affecting the entire phalanx

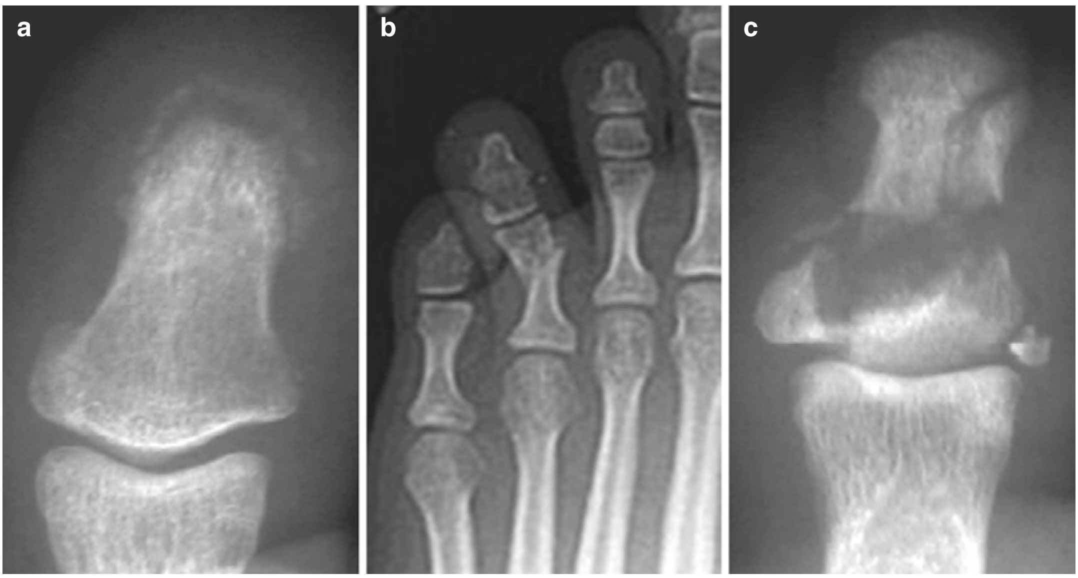

Fig. 34.14 Various fractures of the distal phalanx of the hallux. (**a**) Avulsion of the tuft. (**b**) Transverse fracture of the shaft. (**c**) Highly comminuted fracture of the phalanx with intra-articular involvement

Radiograph

Patients with suspected phalangeal fractures should have AP, oblique, and lateral radiographs of the toe but not the entire foot. These views will allow delineation of the fracture and amount of displacement.

Management

First Proximal Phalanx Fracture

Nondisplaced or minimally displaced fractures can be treated with buddy taping and a hard-soled shoe, and weight bearing as tolerated. Displaced fractures should be treated with closed or open reduction and fixation with crossed K-wires, lag screws, or even plating with mini-implants. Displaced fractures of the MTP joint should be treated with reduction and stabilisation. Such fractures often are quite comminuted, and anatomical reduction may be difficult. If the MTP joint is functioning normally, then the interphalangeal joint is less important. Post-traumatic arthritis of the interphalangeal joint can be easily treated with fusion, if it develops.

Paediatric epiphyseal injuries of foot are rare but can lead to deformity if left untreated (Fig. 34.15).

Fig. 34.15 Displaced Salter-Harris type II fracture of the proximal phalanx of a child's fifth toe. Physis can be seen in the proximal aspect of the other phalanges

Surgical Tips and Tricks

Hallucal Fractures

If the fracture is unstable or an acceptable reduction cannot be obtained, the patient is treated surgically. After anaesthetizing the toe with digital block, the surgeon holds the tip of the toe, applies longitudinal traction, and manipulates the bone fragments into proper position. In most cases, this is done by simply adjusting the direction of traction to correct any shortening, rotation, or malalignment. To unlock fragments, it may be necessary to exaggerate the deformity slightly as traction is applied or to manipulate the fragments with one hand while the other maintains traction. Following reduction, the nail bed of the fractured toe should lie in the same plane as the nail bed of the corresponding toe on the opposite foot. If it does not, rotational deformity should be suspected. Unless it is fairly subtle, rotational deformity should be corrected by further manipulation. If the fracture is unstable (Fig. 34.16a) or an acceptable reduction cannot be obtained, the patient is treated surgically. The focus is on obtaining length, rotation, and alignment of the

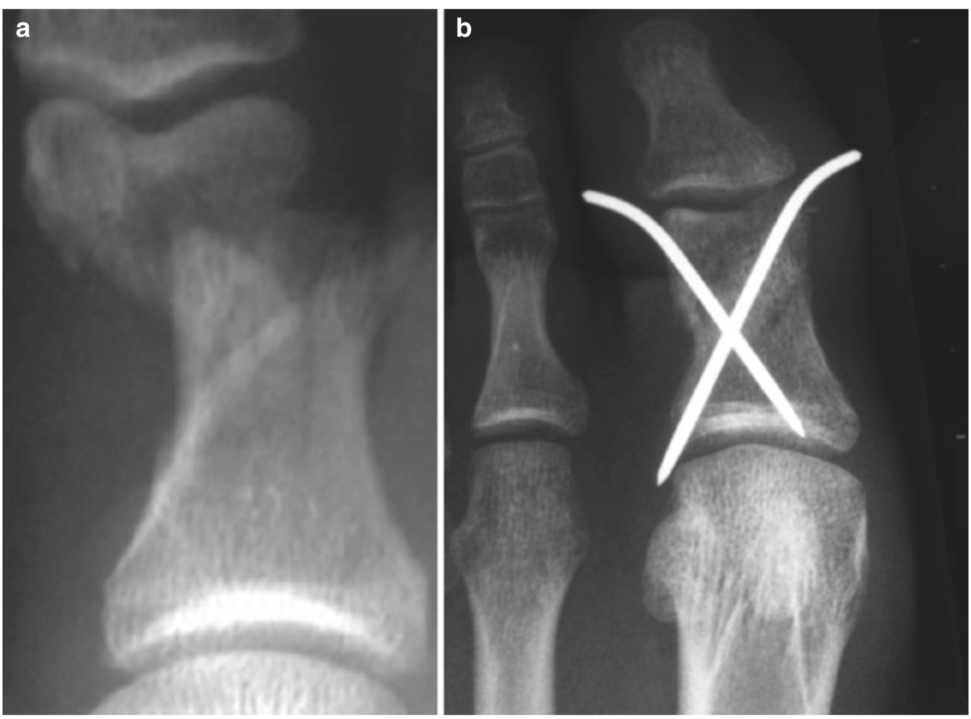

Fig. 34.16 Displaced proximal phalanx fracture (**a**) fixed by percutaneous K-wire in crossed manner (**b**)

toe. Initially, percutaneous fixation with K-wires is attempted from tip to base in oblige or cross manner (Fig. 34.16b). K-wires are usually left in for 6–8 weeks, based on radiographic evidence of healing. If percutaneous fixation is unsuccessful, open reduction and internal fixation is necessary.

Fractures of the Lesser Toes

Although surgery rarely is required for patients with fractures of the lesser toes, K-wire fixation is recommended for patients with open fractures, fracture dislocations, displaced intra-articular fractures, and fractures that are difficult to reduce.

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