Chapter 10
Fractures of the Foot

Keng Suan Khor and Nima Heidari

10.1 Epidemiology

Fractures of the foot are uncommon in childhood and account for 5–8% of all fractures and 7% of all physeal injuries. The forefoot is the most common site of injury comprising two-thirds of the fractures.

The high percentage of radiolucent skeletal structures and the resilient soft tissue coverage contribute to the difficulty in evaluating the severity of injury and compartment syndrome of the foot may occur in the absence of any fractures. Fall from a height is the most common mechanism of injury in forefoot fractures, whereas fractures of the mid- and hind-foot are associated with high-energy trauma.

K.S. Khor, MBBS, BSc (Hons), MRCS (✉)
T&O SpR Percivall Pott Rotation, London, UK
e-mail: kengsuan@gmail.com

N. Heidari, MBBS, MSc, FRCS (Tr&Orth)
Consultant Orthopaedic and Trauma Surgeon,
The Royal London Limb Reconstruction Service,
The Royal London and Barts and The London
Children's Hospitals, Barts Health, London, UK

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10.2 Diagnosis

10.2.1 Clinical Features

A full assessment of the injured foot includes a history and clinical examination. The injury is often not witnessed in the child. A careful examination of the soft tissues and observation to assess the child's ability to bear weight on the injured limb is essential.

Crush injuries carry the risk of compartment syndrome even in the absence of fractures. Close monitoring of a significantly swollen foot is mandatory and the patient should be admitted for elevation. Pressure recording maybe helpful in the unconscious polytraumatised patient but otherwise the decision to perform compartment decompression should be based on clinical suspicion.

Open fractures require administration of tetanus vaccine, antibiotics, debridement and skeletal stabilisation in accordance with established protocols such as the BOAST 4 guidelines.

10.3 Imaging

Routine radiographs include AP and oblique views. When displacement or dislocation at the tarsometatarsal joints is suspected or a fracture of the talus or calcaneum may be present, a true lateral projection is mandatory. In fractures of the calcaneum, an axial projection provides information about calcaneal widening and deformity in the coronal plane.

A CT scan is invaluable in delineating the exact anatomy of calcaneal fractures and aids in preoperative planning. An MRI scan is useful in the diagnosis and assessment of ligamentous injuries. These imaging modalities are also indicated when a tarsal coalition is suspected.

Accessory bones can be mistaken for fractures and are occasionally bipartite. If doubt exists as to whether they are fractured, then either a CT scan to visualize the bone more clearly or an MRI scan which will show bone oedema and soft tissue contusion in the presence of a fracture can help to make a diagnosis (Table 10.1).

10.4 Fractures of Calcaneum

10.4.1 Epidemiology

Calcaneal fractures account for 1–2% of all fractures in adults and some 65% are intra-articular. In contrast this is a rare injury in children (below the age of 14) with the majority (70%) being extra-articular. In adolescents as the skeleton nears maturity the fracture patterns tend to resemble those of the adult with a greater proportion (60–80%) being intra-articular.

As in the adult population the majority of injuries are as a result of a fall from a height (47%), road traffic accidents (15%) and lawnmowers (13%). Up to one-third are associated with other fractures, with lower extremity fractures occurring more frequently than lumbar spine fractures. Fractures in children and adolescents also tend to be less comminuted. This may reflect the fact that these fractures in children are much lower energy injuries and the more cartilaginous immature calcaneum predisposes it to simpler fracture patterns.

10.4.2 Classification

One of the early and most widely accepted classifications of calcaneal fractures was proposed by Essex-Lopresti. This was then modified by Schmidt and Weiner for use in the paediatric population (Table 10.2).

10.4.3 Diagnosis

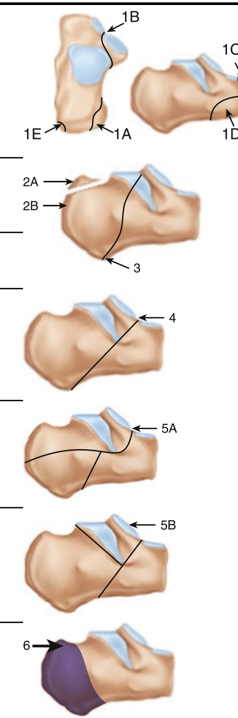
Children sustaining fractures of the calcaneum are likely to have been involved in high-energy trauma. With displaced fractures, the injury to the soft tissue envelope will be directly

TABLE 10.1 Accessory and sesamoid bones of the foot and ankle (Mellado et al. 2003)

Accessory bone	Prevalence (%)	Clinical significance	Differential diagnosis
Os trigonum	1–25	Synchondrotic degeneration or tear Posterior ankle impingement syndrome Flexor hallucis longus tendon entrapment	Shepherd's fracture Cedell's fracture Pseudoarthrosis
Accessory navicular	2–12	Synchondrotic degeneration or tear Posterior tibial tendon dysfunction or tear	Navicular tuberosity avulsion fracture
Os sustentaculi	0.3–0.4	Synchondrotic degeneration Painful syndrome	Isolated fracture of the sustentaculum tali
Os intermetatarseum	1.2–10	Painful syndrome	Lisfranc fracture dislocation
Os supranaviculare	1	Painful syndrome	Cortical avulsion fracture of the navicular or talar head
Os vesalianum	0.1	Painful syndrome	Avulsion fracture at the base of the fifth metatarsal
Os calcaneus secundarius	0.6–7	None	Avulsion fracture of the anterosuperior calcaneal process
Os subtibiale	0.9	None	Medial malleollus avulsion fracture
Os subfibulare	2.1	Painful syndrome	Lateral malleolus avulsion fracture
Os peroneum	9	Painful os peroneum syndrome	Bipartite os peroneum Painful os vesalianum
Hallux sesamoid bones	Close to 100	Fracture, stress fracture, diastasis	Bipartite sesamoid

TABLE 10.2 Schmidt and Weiner classification of calcaneal fractures in children

Extra-articular	1	A. Tuberosity or apophysis B. Sustentaculum tali C. Anterior process D. Distal inferomedial aspect E. Small avulsions off body	
	2	A. Beak fracture B. Avulsion fracture of Achilles tendon insertion	
	3	Linear fracture not involving subtalar joint	
Intra-articular	4	Linear fracture involving subtalar joint	
	5	A. Tongue type	
		B. Joint depression type	
Tissue loss	6	Significant bone loss of posterior aspect with loss of Achilles tendon insertion	



related to the energy of the injury. The foot is often very swollen with substantial bruising and blistering. The possibility of compartment syndrome must be considered.

Standard radiographs for the calcaneum include the lateral and axial projections. Oblique views may help with identifying anterior process fractures. Bohler's angle has been used in determining the presence of an intra-articular fracture and to quantify the degree of displacement. In adults the angle is quoted as being between 20° and 40°. In young children, the range is higher than in the adult, due to the incomplete ossification of the calcaneus. It then rapidly increases with age. By the age of 7 years the estimated mean angle is 42°. The angle tends to decline towards adult values as the child enters adolescence. Measuring the non-injured foot angle is recommended for comparative purposes, although in the case of displaced fractures the modality of choice is a CT scan.

10.4.4 Treatment

The great majority of calcaneal fractures in growing young children can be treated non-operatively due to the potential for remodelling. In the adolescent, fractures resemble the patterns seen in adults and the remodelling potential is greatly reduced. In this group, excellent results have been reported with the operative treatment of displaced intra-articular fractures.

The difficulty in determining how to treat calcaneal fractures in children lies with deciding whether the remaining remodelling process will sufficiently correct the ensuing fracture deformity.

10.4.4.1 Non-operative Treatment

Once the threat of compartment syndrome has abated, a below knee plaster maybe applied for comfort. It should be left on for 6 weeks during which excessive bruising or blistering should be regularly reviewed, potentially with windows in the plaster.

10.4.4.2 Operative Treatment

The extended lateral approach is typically the approach used for open reduction, internal fixation. Surgery should be performed once the soft tissue swelling has settled. A delay of up to 2 weeks is acceptable. A suction drain is advocated for the first 24 h to avoid a wound haematoma that can lead to wound breakdown. Following the closure of the wound, a below knee back slab is applied and the limb elevated. There is a high rate of wound complication and so the wound should be reviewed after 24 h. Protection of the limb in a plaster is advisable for 6 weeks. The wound should be reviewed regularly. During this period the patient should not bear weight through the foot (Fig. 10.1).

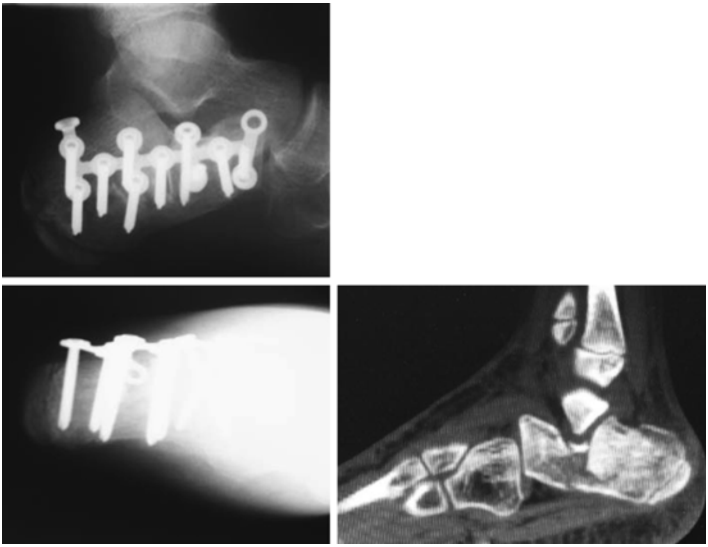


FIGURE 10.1 Comminuted fracture of a calcaneum in a 13 year old child – a CT scan of the injury and post operative radiographs (Reprinted with permission from Benson et al. (2009) *Children's Orthopaedics and Fractures*, Springer)

10.4.5 Delayed Presentation

Many undisplaced and low energy calcaneal fractures are missed in younger children. These tend to heal without consequence. In children below the age of 10, there is good evidence that even articular displacement remodels and the final outcome is good.

10.5 Fractures of Talus

10.5.1 Epidemiology

Fractures of the talus are rare and account for only 0.008% of all childhood fractures. These are often high-energy injuries and concomitant injuries must be ruled out. Significant consequences of these fractures include avascular necrosis as well as post-traumatic arthritis due to malalignment.

10.5.2 Types of Fractures

Fractures most commonly occur at the talar neck, which were classified by Hawkins (Table 10.3). This classifies the injury according to the degree of displacement of the talar neck and subluxation of the tibio-talar, subtalar and talo-navicular joints. The Marti/Weber classification is also commonly used (Table 10.4). Eberl reported less severe injuries (Marti/Weber type I and II) in younger children, in contrast to older children who were prone to fracture-dislocations requiring operative fixation (Marti/Weber type III and IV). This may be due to the more flexible cartilaginous talus, which is less likely to fracture.

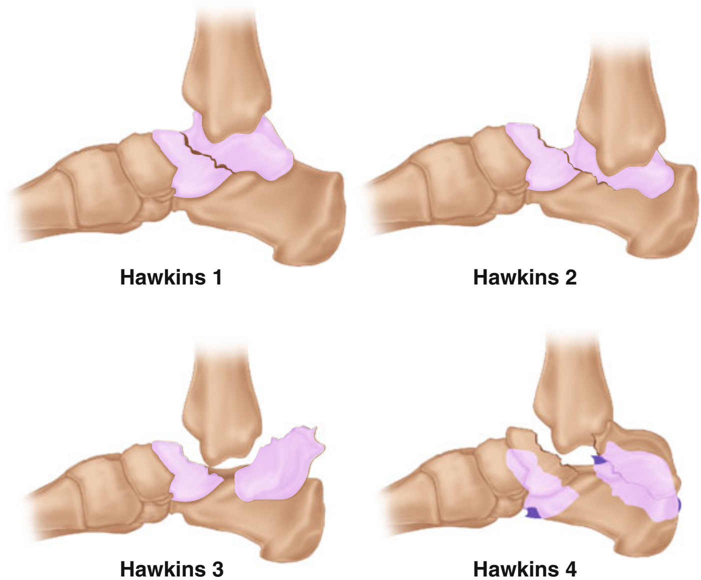
10.5.3 Treatment

Non-operative Treatment

The foot and ankle are immobilised in a cast for 6–8 weeks. The patient is not allowed to bear weight on the injured leg.

Table 10.3 Hawkins Classification of talar neck fractures

Type I	Undislocated talar neck fractures
Type II	Dislocation at the subtalar joint
Type III	Dislocation at the subtalar and ankle joints
Type IV	Dislocation at the subtalar, talonavicular and ankle joints



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20° of plantar flexion at the ankle will help reduce any displacement of the talus. In undisplaced fractures, a below knee cast will suffice.

10.5.3.1 Operative Treatment

Open reduction and internal fixation to achieve anatomical reduction will reduce the risk of avascular necrosis in more severe or displaced fractures [Fig. 10.2].

TABLE 10.4 Marti/Weber classification of talar fractures

Type i	Distal talar neck and talar head fractures, peripheral fractures and osteochandral flakes
Type ii	Undisplaced talar neck and corpus fractures
Type iii	Dislocated talar neck and corpus fractures
Type iv	Proximal talar neck fractures with corpus tali luxated out of the intermalleolar space or comminuted fracture

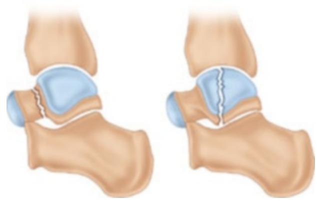
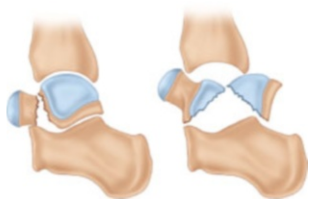
Type I : Distal talar neck and talar head fractures, peripheral fractures and osteochandral flakes	
Type II : Undisplaced talar neck and corpus fractures	
Type III : Dislocated talar neck and corpus fractures	
Type IV : Proximal talar neck fractures with corpus tali luxated out of the intermalleolar space or comminuted fracture	

FIGURE 10.2 Talar neck fracture (Hawkin's type II). With fixation (Reprinted with permission from Benson et al. (2009) *Children's Orthopaedics and Fractures*, Springer)

10.5.3.2 Follow-Up

Regular radiographs should be taken to monitor for evidence of subchondral osteopenia of the talar dome, which is an indicator of talar viability. Hawkins described this subchondral lucency when there was a good vascular supply in the setting of disuse. A negative Hawkins sign is observed when there is progression to sclerosis, indicative of avascular necrosis (AVN). In suspected AVN, the patient should be non-weight bearing for a further 4 weeks and be investigated with an MRI scan. Once AVN is confirmed, walking aids may be needed for mobilisation and subsequent repeat MRI or bone scans may be needed for monitoring.

10.6 Midfoot Fractures

Midfoot injuries in children are rare and are often caused by high-energy trauma.

10.6.1 Chopart Joint Injuries

Chopart fracture-dislocations are rare, high-energy injuries, which involve the mid-tarsal joints. Inversion injuries result in medial dislocations whereas eversion injuries cause lateral dislocations. Urgent reduction is required as these injuries have a poor prognosis.

10.6.2 Fractures of the Navicular

The navicular serves as the keystone to the medial arch of the foot. Displaced fractures must be treated with open reduction and internal fixation to maintain the length and height of the medial arch. After surgery and for non-displaced fractures, patients are immobilised in a Sarmiento cast for 4–6 weeks. Once there is evidence of clinical and radiological union, they can increasingly bear more weight through the foot. Metalwork is removed 3–4 months postoperatively.

10.7 Metatarsal Fractures

10.7.1 Epidemiology

In children, up to two-thirds of all fractures of the foot involve the metatarsal bones. Fractures of the second, third, and fourth metatarsals are frequently associated with fractures of another metatarsal, whereas the majority of first and fifth metatarsal fractures are isolated and account for 85% of all metatarsal fractures. They occur as a result of direct or indirect forces. Fractures sustained at the base of the metatarsals tend to be due to indirect force, and shaft and head fractures result from direct trauma to the foot.

Children below the age of 5 tend to have more fractures of the first metatarsal whereas those over the age of 5 tend to have fractures of the fifth metatarsal. Fractures of the base of the fifth metatarsal are the most common isolated injury of the foot. The fracture line is often perpendicular to shaft of the bone and should not be confused with the proximal apophysis (os vesalanium), which is parallel to the long axis of the bone (Fig. 10.3).

Figure 10.3 Base of fifth metatarsal fracture and apophysis – AP and oblique view of the same patient

10.7.2 Diagnosis

Fractures of the base of the metatarsals may indicate an accompanying injury to the tarsometatarsal joints. Multiple metatarsal fractures indicate a severe injury and the treating clinician must be cognizant of the possibility of compartment syndrome.

10.7.2.1 Stress Fractures

Although more commonly reported in the adult, these fractures are rarely observed in children. Stress fractures should be considered in the differential diagnosis of young athletes. If the fracture is not initially visible on initial radiographs, repeat radiographs 2–3 weeks later may show callus formation. Increasingly, MRI is recognized as the study of choice in these injuries. The treatment is generally non-operative with cast immobilisation for up to 6 weeks and the child can bear weight through the foot once the symptoms have settled.

10.7.3 Treatment , Indication for Surgery, Follow-Up

The majority of metatarsal fractures can be treated non-operatively. A backslab and elevation for the first few days will allow the swelling to reduce. A cast can then be applied for 3–6 weeks and the child allowed to mobilise as comfort allows in the cast. Grossly displaced fractures in children nearing skeletal maturity should be treated with closed reduction and k-wire fixation.

In the presence of an open fracture, well-established protocols of antibiotic administration, debridement, fracture stabilisation and soft tissue cover should be adhered to.

10.7.4 Complications

Fractures at the base of the first metatarsal may involve the growth plate. Growth arrest here may lead to shortening of the first metatarsal and subsequent deficiency of the medial longitudinal arch. There is little data on the long-term outcome of metatarsal fractures in children.

10.8 Phalangeal Fractures

10.8.1 Epidemiology

Fractures of the phalanges in the paediatric foot are usually caused by a direct trauma from a fallen object or from kicking an object. In younger children they are quite uncommon and the incidence increases with age. About one quarter of these injuries occur in the great toe.

10.8.2 Classification

Phalangeal fractures may be intra- or extra-articular. Those involving the physis can be classified as per the Salter and Harris classification.

10.8.3 Diagnosis

See above.

10.8.4 Treatment, Follow-Up, Complications

The majority of the phalangeal injuries tend to be undisplaced. "Neighbour strapping" to the adjacent uninjured toe, which serves as a splint, is adequate. Malrotation should be corrected. The nail bed of the injured toe should be in the same plane as the others. To avoid maceration when taping, gauze should be placed between the toes. This may be continued for 3–4 weeks or until the child is asymptomatic. During this period it may be unwise for the active child to wear open toed shoes as unintentional contact with an object may be very painful.

Intra-articular injuries involving the proximal phalanx of the great toe include Salter-Harris type III and IV injuries. If the fractures involve more than a third of the joint surface and are displaced, open reduction and internal fixation is indicated. Fixation can be carried out with a K-wire, which is left proud of the skin and then removed after 3 weeks. Leaving such fractures untreated may lead to pain and instability (Fig. 10.4).

FIGURE 10.4 Intraarticular fracture of the proximal phalanx of the big toe. Despite fracture displacement, the patient was treated conservatively. Two years after the injury, revision surgery was required due to increasing pain and instability. The final outcome was good

10.9 Compartment Syndrome

Compartment syndrome of the foot is uncommon in children but its treatment and operative decompression does not differ to that of the adult. It should be noted that it may occur in the absence of fractures particularly in crush and high-energy injuries. As with compartment syndrome of the limbs, neurovascular compromise is a late finding and should not be relied upon as a diagnostic guide. Compartment pressure monitoring has its place in the assessment of the polytraumatised child with an altered level of consciousness. In a cooperative and awake child, the decision to surgically decompress the foot is made clinically and not based solely on compartment pressure measurements. A massively swollen foot that has been recently involved in high-energy trauma, exhibiting plantar ecchymosis and extensive bruising is in imminent danger of developing compartment syndrome.

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