Metatarsal fractures

Anatomy and function

The human foot combines mechanical complexity and structural strength.

Structurally, the foot has three main parts: the forefoot, the midfoot and the hindfoot. The forefoot is composed of the five toes (called phalanges) and their connecting long bones (metatarsals).

The foot has two important functions: weight bearing and propulsion. These functions require a high degree of stability. In addition, the foot must be flexible so it can adapt to uneven surfaces. The multiple bones and joints of the foot give it flexibility, but these multiple bones must form an arch to support any weight.

The foot has three arches. The medial longitudinal arch is the highest and most important of the three arches. It is composed of the calcaneus, talus, navicular, cuneiforms, and the first three metatarsals. The lateral longitudinal arch is lower and flatter than the medial arch. It is composed of the calcaneus, cuboid, and the fourth and fifth metatarsals. The transverse arch is composed of the cuneiforms, the cuboid, and the five metatarsal bases.

The arches of the foot are maintained by the shapes of the bones and by the ligaments. In addition, muscles and tendons play an important role in supporting the arches.

The phalanges are connected to the metatarsals by five metatarsal phalangeal joints at the ball of the foot. The forefoot bears half the body's weight and balances pressure on the ball of the foot (*Figure 1a* and *b*).

The first metatarsal bone bears the most weight and plays the most important role in propulsion. It is the shortest and thickest. It also provides attachment for several tendons. The second and third metatarsals are relatively fixed in position within the foot; the first, fourth and fifth are relatively mobile. More stress is placed on the second and third metatarsals when ambulating, so these are at increased risk of stress fracture.

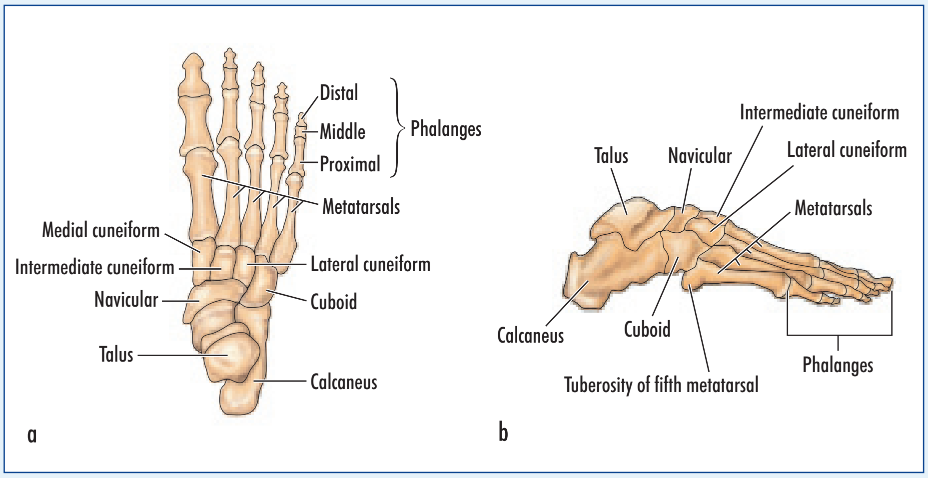

Figure 1. a. Top view of bones of the foot. b. Lateral view of bones of foot.

The fifth metatarsal, which is approximately 1.5 cm from the proximal pole of the bone, bears greater stress in those who oversupinate when they walk or run. The fifth metatarsal also has a diminished blood supply and thus decreased ability to heal.

Radiological anatomy

On the anteroposterior view, the lateral border of the first metatarsal should be aligned with the lateral border of the medial cuneiform. The medial border of the second metatarsal should be aligned with the medial border of the intermediate cuneiform bone.

On the oblique view, the medial and lateral border of the third metatarsal should be aligned with the medial and lateral borders of the lateral cuneiform bone. The medial border of the fourth metatarsal should be aligned with the medial border of the cuboid bone. The fourth and fifth metatarsals are aligned with the cuboid bone, but the lateral part of the fifth metatarsal can project beyond the margin of the cuboid bone, up to 3 mm.

The distance between the base of the first and second metatarsals and the medial and intermediate cuneiform is more than the distance between other corresponding joints.

If a lateral image is obtained a line through the long axis of talus bone and the long axis of first metatarsal bone should be straight if there is no dislocation.

Mechanisms of injury

Metatarsal fractures are usually caused by the blow of a heavy object dropped onto the forefoot or by a twisting injury. Fractures of the shaft can be caused by twisting of the body with the toes fixed, applying torque to the foot.

Avulsion (pull-off) fractures occur particularly at the base of the fifth metatarsal. A Jones fracture (base of fifth metatarsal) is caused by inversion of the foot, which produces tension on the peroneus brevis tendon and on the lateral cord of the plantar aponeurosis. In this type of fracture, significant displacement is absent. This type of fracture is more prone to non-union.

Distal fractures, also called dancer's fractures, are caused by a rotational force caused by axial loading with the foot in a plantigrade position.

The Lisfranc joints are the tarsometatarsal joints. A Lisfranc fracture dislocation is caused by falling from a height, falling down stairs or stepping off a curb.

Mechanisms of injury are either rotation around a fixed forefoot (e.g. falling from a horse with the foot caught in the stirrup) or longitudinal compression of foot. In this second mechanism, the metatarsal head is fixed, with weight of body on the hindfoot against the base of metatarsals

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along with rotation; these forces result in a distal dorsal dislocation of the metatarsal.

Stress fractures are common in the second and third metatarsal necks and at the proximal portion of the shaft of the fifth metatarsal. Athletes and soldiers seem to be more prone to this type of injury. Patients usually report increased intensity or duration of exercise regimen. Dull pain occurs initially only with exercise, progressing to pain at rest. The pain starts as diffuse, then localizes to the site of the fracture.

A stress fracture is not the result of a single occurrence, but rather an ongoing process. They are rare before adolescence as is bilateral presentation. In sedentary individuals, the cause is usually related to unaccustomed activity.

Mechanisms may involve repetitive stress, usually as a result of frequent impact weight-bearing exercise eventually yielding to a fracture caused by continued loading. Biomechanical abnormalities, such as excessive pronation, hypersupination, lower extremity malalignment, external or internal femoral rotation and limb length discrepancy, can all lead to an alteration in normal gait, which can then lead to stress fractures.

Insufficiency fractures are caused by normal stress on a weakened bone. This injury is seen in people with osteoporosis, and commonly affects postmenopausal women.

Clinical picture and investigations

The cardinal signs and symptoms are pain, deformity, crepitus, swelling, bruising and increased pain on weight bearing. In a fracture of the fifth metatarsal, pain and tenderness are present at the base of fifth metatarsal, along with swelling, ecchymosis and difficulty in weight bearing. This fracture is sometimes hard to differentiate from a soft tissue ankle injury, because the swelling and pain for both injuries may be just inferior to the lateral malleolus.

The head of the second metatarsal head is most commonly affected, although other bones can be involved as well.

Proper history taking in patients with symptoms and suggestive mechanisms of injury is essential.

Radiography is the first and often the only investigation required for the diagnosis of fractures. Radiographs can be used to diagnose all acute fractures, dislocations, and established stress fractures.

Bone scanning is more sensitive than plain radiography and is indicated when a stress or acute fracture is suspected and radiographs are negative. Bone scanning is not a specific investigation.

Although magnetic resonance imaging (MRI) is more sensitive than radiography and bone scanning, it is used only for the assessment of soft tissue structures and ligamentous injuries. MRI is the most sensitive technique for imaging stress fractures of the foot and can depict bone marrow oedema even before increased uptake is seen on bone scans.

Computed tomography (CT) scanning is useful for finding avulsion fractures and comminuted fractures, and to assess for intra-articular extension.

Small avulsions can be missed on radiographs. In the early stages of stress fracture, radiographs can be normal, or they may show only subtle periosteal reaction, which can be easily missed. Radiography cannot be used to assess soft tissue and ligamentous disruption.

Although CT and MRI are more sensitive than radiography, they are not cost-effective and are not indicated for the diagnosis of fractures.

Although bone scanning is sensitive, it can still miss some stress fractures in the early stages.

Classification systems for fifth metatarsal fractures

Many classifications apply to fracture of the fifth metatarsal. A simple classification for fractures of the proximal end of fifth metatarsal divides them into:

1. Fractures of the tuberosity
2. Fractures of the proximal metatarsal within 1.5 cm of the tuberosity.

Acute fractures, Jones fractures, and stress fractures can be described as early, delayed union, or non-union fractures.

The Stewart classification (1960) of fifth metatarsal fractures is as follows:

1. Type I: extra-articular fracture between the metatarsal base and diaphysis
2. Type II: intra-articular fracture of the metatarsal base
3. Type III: avulsion fracture of the base
4. Type IV: comminuted fracture with intra-articular extension
5. Type V: partial avulsion of the metatarsal base with or without a fracture.

The zonal classification reported by Dameron (1975) and Lawrence and Botte (1993) categorizes metatarsal fractures by the region affected: zone 1 corresponds to the tuberosity, zone 2 corresponds to Jones fractures, and zone 3 is the diaphysis (*Figure 2*).

Figure 2. Spiral fracture of distal shaft of fifth metatarsal.

Figure 3. Jones fracture.

Figure 4. Fracture of proximal shaft of first metatarsal.

Common fractures

Fractures can affect any metatarsal, but the fifth metatarsal is most commonly affected. The fracture can be transverse, oblique or comminuted. Longitudinal linear fractures are extremely rare.

The two most common fractures in the fifth metatarsal are a fracture at the tip of the tuberosity and a transverse fracture 1.5–2 cm from the tuberosity; the latter is called a Jones fracture (*Figure 3*).

The head of the first metatarsal is thought to bear one third of body weight. Three types of fracture predominate: avulsion, proximal shaft (*Figure 4*) and mid shaft. Shorter and wider than the other metatarsals, the first metatarsal also has a lack of interconnecting ligaments between itself and the second metatarsal. This allows for independent motion.

Figure 5. Fracture of distal shaft of third metatarsal.

Figure 6. Fractures of second and third metatarsal heads (oblique view).

Fractures of the middle metatarsals can be isolated or multiple (*Figures 5* and *6*). Oblique and transverse diaphyseal fractures predominate. With regard to treatment, emphasis, as with the first metatarsal, is on the resulting position of the metatarsal head.

Lisfranc dislocations

Two types of Lisfranc dislocation have been described: homolateral and divergent.

Figure 7. Lisfranc fracture-dislocation: a fracture of the base of the second metatarsal and a lateral dislocation of the second metatarsal.

Figure 8. Lisfranc dislocation with a fracture of the base of the third and fourth metatarsals.

In the homolateral type, all of the metatarsals are dislocated to one side. Usually, the second to fifth metatarsals are dislocated, but occasionally all of the metatarsals are affected.

Lisfranc dislocations are associated with fractures of the base of the second metatarsal (*Figure 7*), fractures of the cuboid bone, fractures of the shaft of the other metatarsal bones (*Figure 8*), dislocations of the middle and medial cuneonavicular joints, and fractures of the navicular bone. The base of the second metatarsal is relatively fixed compared with the other metatarsal bones. Therefore, it is involved in both types of Lisfranc fractures.

This dislocation is overlooked in as many as 20% of cases if the alignment is not carefully evaluated. Lisfranc dislocations should be suspected if a gap of more

Figure 9. Stress fracture with extensive periosteal reaction on either side of the third and fourth metatarsals.

than 5 mm is present between the bases of the first and second metatarsals or between the medial and middle cuneiforms.

The radiographic findings of a stress fracture depend on the bone involved and the stage of disease. Radiographs are normal in the early stages of the disease, and stress fractures appear as well-defined linear lucency or fluffy periosteal reactions by 7–10 days. The periosteal reaction is variable and is occasionally florid (*Figure 9*).

The head of the second metatarsal, and occasionally the third metatarsal, are commonly affected. The first metatarsal is injured in only 10% of metatarsal stress fractures and involves a different kind of reaction (the endosteal variety) with linear sclerosis. Periosteal reaction is not common in this type of injury.

The base of the second metatarsals can be affected in ballet dancers. The proximal aspect of the shaft of the fourth and fifth metatarsals is affected, and the pattern is that of a linear lucency, which is slow to heal. Fractures in the sesamoid bones are also seen in ballet dancers.

Management and definitive treatment in accident and emergency

Base of fifth metatarsal fractures and Jones fractures can mostly be treated in non-weight-bearing plaster of Paris (POP) casts for 6–8 weeks. However, it is advisable to arrange orthopaedic follow up in all cases as some can progress to delayed or non-union and if significant displacement exists, should be considered for internal fixation. If symptoms are slight, a crepe bandage or similar support for 2–3 weeks is indicated. All athletes should be considered for internal fixation to facilitate early return to sport and minimize non-union rates.

Shaft fractures of the metatarsals should be assessed as any other fracture in terms of displacement and angulation. There are no fixed criteria for acceptable or unacceptable position of the head, but problems of transfer metatarsalgia and shoe wear are common if there are significant changes in the normal position of the head. Normally 10° of deviation in the dorsal/plantar plane or 3–4 mm of translation in any plane requires active correction, either manipulation or gravitational traction. An Aircast boot or a below-knee POP cast with weight bearing as tolerated, are the mainstay of conservative closed treatment thereafter.

Multiple adjacent fractures with significant soft tissue injury, or fractures which are significantly displaced and angulated and resistant to manipulation, require open reduction and fixation with K-wires. A plate may be used if the soft tissues are intact. Traction remains an option if control is difficult to achieve or the fracture extends into the head and metatarsophalangeal joint.

Conservative treatment, or to hold position after fixation, is a short-leg POP cast for 4–6 weeks. This may be removable after the first 2 weeks. Position of the foot is as above. Weight bearing is encouraged on the heel, as tolerated.

All suspected Lisfranc injuries should be referred to the orthopaedic team immediately for assessment as the mainstay of treatment is open reduction and internal fixation. Closed reduction and percutaneous pinning may be attempted. Prognosis of Lisfranc injuries without fracture is poor as a result of late midfoot collapse.

Treatment of stress fractures depends on the time the diagnosis was made. In cases of fresh injury, rest, ice, elevation and compression (RICE) are very helpful as well as anti-inflammatory medication. An Aircast boot may be used if weight bearing is to be allowed, but an elastic bandage and non-weight bearing status is adequate. Total rest and refrainment from exercise and sport for 4–8 weeks is necessary. Metaphyseal fractures heal quicker than articular or cortical ones.

Heat is helpful in increasing blood flow to the area, which can help to accelerate bone healing. The patient can begin rehabilitation when pain free, but not necessarily return to sporting activity. The patient must have full range of motion in the joints in the injured extremity, have redeveloped the flexibility of the muscles of that limb and developed strength, endurance, propioception, agility and cardiovascular reserve before returning to full competition. A good training programme, the use of proper footwear, impact surfaces and orthoses can be important preventative measures to take in the recurrence of stress fractures. In the athlete, the stress fracture is the epitome of an overuse injury and, as such, signals the need to investigate training habits, equipment and athletic techniques. **BJHM**

Conflict of interest: none.

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KEY POINTS

- Structurally, the foot has three main parts: the forefoot, the midfoot, and the hindfoot.
- The first metatarsal bone bears the most weight and plays the most important role in propulsion.
- More stress is placed on the second and third metatarsals when ambulating, so these are at increased risk for stress fracture.
- Metatarsal fractures are usually caused by the blow of a heavy object dropped onto the forefoot or by a twisting injury.
- Avulsion (pull-off) fractures occur particularly at the base of the fifth metatarsal.
- Lisfranc injuries are often missed. Expert opinion should be sought if there is any doubt as improper management leads to significant morbidity.
- Stress fractures are common in the second and third metatarsal necks and at the proximal portion of the shaft of the fifth metatarsal. Mechanisms may involve repetitive stress, usually as a result of frequent impact weight-bearing exercise, eventually yielding to a fracture as a result of continued loading.
- Shaft fractures of the metatarsals should be assessed as any other fracture in terms of displacement and angulation. Normally 10° of deviation in the dorsal/plantar plane or 3–4 mm of translation in any plane requires active correction; manipulation or gravitational traction.