

METATARSAL FRACTURE TREATMENT

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INTRODUCTION

Metatarsal fractures are one of the most common injuries to the foot, and can often cause prolonged disability if they are initially overlooked or mistreated. A clear understanding of the mechanism of injury, anatomy including vascular supply, and principles of closed and open reduction need to be applied to be successful in treating this condition. The primary goal of metatarsal fracture treatment is to help the patient regain full function of the injured foot. This article is written to provide a guideline to the treatment of metatarsal fractures.

EPIDEMIOLOGY AND RISK FACTORS

Metatarsal fractures are second only to toe fractures as being the most common type of fracture sustained in the foot (1). In fact, acute metatarsal fractures account for 35% of all foot fractures (2), and approximately one-third of metatarsal fractures involve the shaft or distal portion of the metatarsal in the adult population (1). In the pediatric population, 61% of all fractures are located in the metatarsals (3). Most metatarsal fractures are caused by low-energy trauma such as a simple twist or fall from a standing height in the adult population and children older than five-years-old. Falling from a height is the most common cause seen in pediatric patients younger than five-years-old (4). Petrisor et al found that fractures of the metatarsals usually occurred in the second to fifth decades, and with increasing frequency from the first metatarsal (1.5%), central metatarsals (10%), to the fifth metatarsal (68%) in their retrospective study (5).

Some populations are at a greater risk of developing traumatic metatarsal fractures including elderly women with osteoporosis, and patients that have had diabetes for longer than 25 years (2).

MECHANISM OF INJURY

Metatarsal fractures are either due to direct or indirect injuries. They typically are a result of low-impact trauma. However, high-impact trauma, including motor vehicle accidents, can also result in metatarsal fractures. Indirect twisting forces can apply torque to the foot, and produce

fractures to the metatarsal shafts, particularly spiral fractures. Heavy falling objects can apply direct force, and lead to fractures of any metatarsal at any location. Avulsion fractures can occur, especially to the base of the fifth metatarsal, which has been suggested to be caused by the lateral band of the plantar fascia (6). Stress fractures can arise due to locally high repetitive loads. Any mechanical reason found to be the causative factor of overload should be addressed at the same time as the stress fracture.

DIAGNOSIS

A thorough clinical and radiographic evaluation is essential in the initial management of metatarsal fractures. Typically patients that present with metatarsal fractures have an antalgic gait. Dorsal edema and ecchymosis to the foot develops quickly after the injury (Figure 1). Skin integrity should be assessed to rule out any open fracture or crush injury that may devitalize the skin. In the acute setting, it is fairly easy to discover pinpoint tenderness over the fracture site. Palpation of nonpitting edema and deformity is readily apparent. Increased edema may make it difficult to localize



Figure 1. Clinical presentation of metatarsal fractures (Courtesy of Craig Camasta, DPM).

the fracture. It is best to examine the contralateral extremity first, and then proceed to the involved extremity focusing on the site most likely to be involved last so that the patient is not guarded throughout the examination. A neurovascular examination should be performed and documented. Metatarsal fractures need to be differentiated from isolated soft tissue injuries. Compartment syndrome should always be suspected, and if present an emergent fasciotomy to prevent tissue or digital loss is required.

Radiographic evaluation for metatarsal fractures consists of a minimum of three views including a dorsoplantar, lateral, and oblique. Initial films should include the whole foot to rule out other potential injuries. Sometimes a second set of films focused on only the forefoot may be required because whole foot radiography tends to overexpose the forefoot and metatarsal head region (7). A lateral view is important to observe any sagittal displacement present. Other studies are rarely warranted. However, a computed tomography (CT) scan or magnetic resonance imaging (MRI) may be useful if the tarsometatarsal joints appear to be involved.

Initial diagnosis of stress fractures is typically clinical. Physical examination reveals pinpoint tenderness overlying the stress fracture site. Pain is generally exacerbated with activity and improves with rest. Bone callus will become apparent radiographically by the third to fourth week. MRI and other advanced studies such as CT or bone scans are generally not necessary.

ANATOMICAL CONSIDERATIONS

First Metatarsal

The first metatarsal has many unique characteristics. It is the thickest, widest, and shortest metatarsal. The base of the first metatarsal is reniform in shape, and articulates with the medial cuneiform. Its base is the site of two powerful musculature attachments. The tibialis anterior inserts at the plantar medial aspect causing dorsiflexion of the first ray, and the peroneus longus tendon inserts into the plantar lateral aspect causing plantar flexion of the first ray. There is no ligament that connects the bases of the first and second metatarsals, and therefore independent motion can occur to allow for adaptability to terrain. The tibial and fibular sesamoids at the plantar aspect of the first metatarsal head serve as two of the six contact points for weightbearing of the forefoot. In essence, the first ray supports one-third of the total weight of the forefoot (8).

The blood supply of the first metatarsal consists of the dorsal metatarsal artery, first plantar metatarsal artery, and superficial branch of the medial plantar artery. There is a

nutrient artery that enters laterally into the distal one-third of the metatarsal. This nutrient artery often arises from the first dorsal artery (9, 10).

Central Metatarsals

The bases of the second, third, and fourth metatarsals articulate with all three cuneiforms, the lateral cuneiform, and the cuboid respectively. There are a series of three ligaments (the dorsal, interosseous, and plantar) that stabilize each metatarsal to their neighbors, with the exception that there is no such connection between the first and second metatarsal bases. The second metatarsal is linked to the medial cuneiform by the Lisfranc ligament. The metatarsal shafts serve as origins for the intrinsic plantar and dorsal interossei, and slips from the tibialis posterior represent the only extrinsic muscle attachments (1). A thick transverse metatarsal ligament connects the metatarsals indirectly distally by joining the plantar plates of the adjacent metatarsophalangeal joints. There is a nutrient artery that enters laterally approximately 3.1 centimeters from the distal articular cartilage of the central metatarsals (11). The metatarsal heads are supplied by dorsal and plantar metatarsal arteries, which form a vascular ring (12). Biomechanically, there is an increasing range of motion through the second to fifth tarsometatarsal joints that allows for adaptability to uneven surfaces by the metatarsal heads. Stress fractures are commonly seen in the second and third metatarsals, and may be due to the limited motion of the second and third tarsometatarsal joints (13).

Fifth Metatarsal

The fifth metatarsal is similar to the first metatarsal in the sense that it has distinguishing characteristics. The proximal tuberosity of the fifth metatarsal is the site for the insertion of the peroneus brevis tendon, and the lateral slip of the plantar fascia. The peroneus tertius inserts at the dorsal aspect of the proximal metaphyseal-diaphyseal junction. The peroneus tertius counteracts the natural inverting force of the tibialis anterior, and acts as a balancing force in forefoot dorsiflexion. The everting power of the peroneus brevis antagonizes the inverting strength of the tibialis posterior. The fifth metatarsal articulates with the cuboid and lateral base of the fourth metatarsal, and has strong ligamentous attachments to both. Dorsal and plantar interossei arise from the metatarsal base medially, and the flexor digiti minimi arises from the fifth base plantarily (14-17). The fifth metatarsal functions independently from the central metatarsals. The blood supply of the fifth metatarsal has been studied extensively. A single nutrient artery enters the medial cortex at the junction of the proximal and middle third of

the diaphysis to supply the metatarsal shaft. The base and tuberosity are supplied by secondary epiphyseal and metaphyseal arteries. The metatarsal head is supplied by the dorsal and plantar metatarsal arteries. The fibular plantar marginal artery also contributes to the blood supply of the fifth metatarsal (18, 19). There are different theories that have been suggested to be the cause of poor healing associated with the proximal metaphyseal-diaphyseal junction of the fifth metatarsal including poor blood supply to this area, or due to the highly mobile lever arm being focused at this fracture site.

TREATMENT RECOMMENDATIONS

First Metatarsal

There are many forces that occur throughout the first metatarsal during ambulation, and it is very important to maintain the normal relationship of the first metatarsal to the foot. In the rare event that a first metatarsal fracture would occur, stress radiographs may be helpful in determining if instability is present. Instability is represented by any displacement that occurs through the fracture site or joint during manual manipulation. Conservative care is supported by the literature with the use of a short-leg nonweight-bearing cast for four to six weeks if an isolated first metatarsal fracture is present, and there is no instability or any other injuries present (7). Protective weightbearing in a cast or cam walker can then be initiated until radiographic and clinical evidence of healing is present. It is important to follow these fractures closely throughout conservative care with radiographic studies to verify that alignment is maintained.

Any instability or loss of normal position of the first metatarsal requires surgical treatment. Preservation of the position of the first metatarsal head in regard to the lesser metatarsals is paramount. The first metatarsal-cuneiform joint can be sacrificed with primary arthrodesis for position and stability with little loss to the effect of the forefoot function. The fracture pattern determines the method of fixation.

Simple fractures are typically treated with lag screw fixation after open reduction. Buttress plating with screw fixation can be utilized for diaphyseal fractures. If comminution is present, and lag screw technique is not possible, bridge plating can be used or external fixation may be required to protect the soft tissue envelope (Figure 2). The goal for treating these fractures is to establish length, position, and minimize further soft tissue damage.

Every attempt should be made to preserve the first metatarsophalangeal joint function during the management of intra-articular first metatarsal head fractures. Smooth Kirschner wires can be used to maintain anatomic alignment

and minimize damage to the cartilage. A cancellous bone graft may be needed for additional support. Screws can be used for large intra-articular fragments, and in the event of severe comminution a first metatarsophalangeal joint fusion may be required for definitive care.

Central Metatarsals

Proper position of the metatarsal heads in the sagittal plane is the most important aspect in treating central metatarsal fractures. Transverse plane deformities are better tolerated, but can be problematic if there is close abutment with adjacent metatarsals. Frontal plane deviation is typically not a concern, and is very rare due to soft tissue attachments between the metatarsal heads. Specific criteria establishing an acceptable position in the literature is sparse. Most often there are two recommendations; surgical treatment is indicated in any fracture that has greater than ten degrees of angulation or greater than three to four millimeters of displacement in any plane (21, 22). Conservative care is warranted if the above mentioned criteria are not present, and there are no other associated injuries (Figure 3). Protective mobilization in a cam boot or hard-soled post-operative shoe can be utilized.

Closed reduction can be attempted for individual or multiple metatarsal head or neck fractures that are deviated. If reduction cannot be maintained, Kirschner wire fixation should be utilized for stabilization. Percutaneous stabilization can be attempted first, however if this is

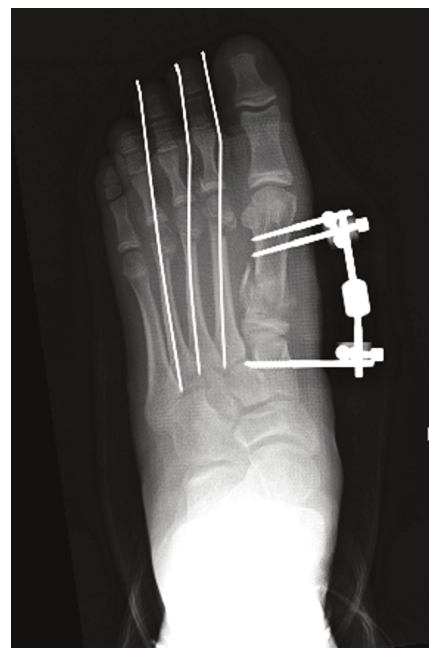


Figure 2. Use of Kirschner wires and external fixation in the surgical repair of multiple metatarsal fractures (Courtesy of Craig Camasta, DPM).



Figure 3. Minimally displaced second metatarsal fracture that can be conservatively treated.



Figure 4. Percutaneous Kirschner wire fixation for the surgical treatment of central metatarsal fractures.

unsuccessful then open reduction is required of displaced metatarsal head and neck fractures. Dorsal longitudinal incisions are recommended, centered over the affected shaft or the web space between adjacent fractures.

There are two methods that are typically described for Kirschner wire fixation. The fixation can either exit distally plantar to the proximal phalanx, or when multiple fractures are present it has been suggested that the base of the proximal phalanx should be captured from the lateral aspect and directed medially down the shaft of the metatarsal to offset the tendency of these fractures to drift laterally (23).

Metatarsal base fractures that are unstable can be fixed with limited open reduction and intramedullary pinning. The tarsometatarsal joint can be crossed for additional stability. Intramedullary fixation is generally effective, and decreases the risk of devascularization (Figure 4). Plate fixation and external fixation have also been utilized. It is pertinent that the distal fragment not be in a dorsiflexed or plantarflexed position in comparison to the other metatarsals after fixation.

Fifth Metatarsals

The fifth metatarsal is the most common location of metatarsal fractures, and much literature has been directed toward its treatment. Generally, the proximal fifth metatarsal is divided into three zones: the first zone (tuberosity), second zone (Jones fracture, or metaphyseal-diaphyseal junction), and third zone (proximal diaphyseal stress fracture) (24-26).

Nondisplaced fractures involving the first zone, distal shaft, or due to a direct blow generally fare well with conservative care. This can consist of a soft Jones dressing with stiff soled shoe, removable cam walker, or weight-bearing cast immobilization. These have all been shown to be equally effective. In adolescents with apophysitis the treatment is the same. Callus formation at the fracture site should be present at six to eight weeks without intramedullary sclerosis. If radiographs demonstrate little or no callus formation at the six to eight week period, an effective alternative to surgery for the management of delayed union and nonunion has been pulsed electromagnetic field therapy. Surgical treatment has been recommended if either displacement of greater than three millimeters occurs, or greater than 30% of the metatarsal cuboid joint articulation is involved. It has also been recommended that athletes with acute fractures in this zone, and non-athletes with delayed union be surgically treated. Intramedullary screw fixation, tension banding, and percutaneous pinning have all been described (27, 28).

Treatment recommendations for acute zone two injuries, or Jones fractures, are controversial. Short leg casting with nonweightbearing for six to eight weeks followed by an additional six to eight weeks of transitioning to full weightbearing activities have shown good results (29). Average healing time with casting has been shown to take approximately 21 weeks (30). Intramedullary screw fixation has been proven to be effective. The literature supports the early surgical treatment in high-performance athletes, and in

the informed patient who prefers surgery versus the risk of nonunion with conservative care. Screws can be cannulated or solid, and generally range from 4.0 to 6.5 millimeters in diameter (31). Screws that are solid and larger in diameter are typically stronger, (32, 33) but considerations to patient size and level of activity need to be applied. Other acceptable methods have been described including tension banding (34), percutaneous pinning (35), and external fixation (36).

Zone three injuries, diaphyseal stress fractures, have an increased risk of nonunion. The type of fracture present, as described by Torg, directs the treatment (37). Type I and II fractures (acute and delayed unions) can be treated conservatively with nonweight-bearing cast immobilization. Type I fractures heal in seven weeks, approximately 93% of the time (38, 39), and type II fractures can take longer to heal, anywhere up to 20 weeks. Type III fractures typically require placement of bone graft and internal fixation for successful treatment (27).

Fifth metatarsal shaft and neck fractures are treated in the same manner as central metatarsal neck and shaft fractures. If there is greater than three to four millimeters of displacement, or angulation of more than ten degrees in the sagittal plane the fracture should be reduced. Conservative care can be utilized for further care, however if reduction cannot be maintained then surgical treatment should be performed. Surgical treatment consists of either open reduction with internal fixation with plates, screws, or circlage wire, or closed reduction with percutaneous Kirschner wire fixation. O'Malley et al treated 35 ballet dancers who sustained a distal fifth metatarsal fracture. Thirty one of the patients were treated conservatively, two were treated with open reduction and internal fixation, and two were treated with percutaneous Kirschner wire fixation. All of the patients returned to the professional level without any pain or restriction (39).

CONCLUSION

Metatarsal fractures are common traumatic injuries seen by the foot and ankle specialist. If proper treatment is performed, most patients will be able to regain full function. Permanent disability can occur if this condition is overlooked, or if treatment is inadequate. There is limited research pertaining to the treatment of metatarsal fractures with the exception of fifth metatarsal fractures, and controversy still exists in the treatment of metaphyseal-diaphyseal fractures of the fifth metatarsal. This update was written to provide current recommendations in the treatment of metatarsal fractures. Location, type, and length of symptoms are all

important factors when determining the treatment of this condition. Conservative or surgical treatment, when utilized appropriately, will help achieve the goal of returning the patient to full function.

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