10 Complications of Metatarsal Fractures

J. Randolph Clements

The First Metatarsal and First Metatarsophalangeal Joint

The first metatarsal is considerably wider and stronger than the lesser metatarsals. It is thought that one third of the body weight is transferred through the first metatarsophalangeal joint during gait [1]. The first metatarsal has cartilage surfaces both proximally and distally. The proximal aspect is reniform, or kidney-shaped, and articulates with the first cuneiform. The distal aspect articulates with the base of the proximal phalanx and the sesamoid complex. The distal aspect is round to allow for sagittal plane motion of the first metatarsophalangeal joint. The first metatarsophalangeal joint has a vertical and transverse axis. The vertical axis allows for abduction and adduction while the transverse axis allows for dorsiflexion and plantar flexion. During propulsion, approximately 65° of dorsiflexion is needed at the first metatarsophalangeal joint [1, 2]. The sesamoid complex is held in position by the medial and lateral flexor hallucis brevis muscles. The two heads of the abductor hallucis are attached on the lateral side of the fibular sesamoid. A portion of the adductor hallucis inserts on the medial side of the tibial sesamoid. The deep transverse intermetatarsal ligament also contributes to sesamoid stabilization and helps to maintain the sesamoids relationship to the lesser metatarsals. This unique anatomic relationship makes minimal displacement of the sesamoid complex intolerable. The topic of turf toe injuries will not be discussed in this chapter. However, the authors believe a brief review of first metatarsophalangeal joint biomechanics is important in order understand reconstruction of complications of metatarsal fractures.

Injuries to the first metatarsophalangeal joint are typically caused by direct trauma. The majority of trauma involving the first metatarsophalangeal joint occurs from hyperdorsiflexion mechanisms [2, 3]. These mechanisms can create dislocations with or without an osseous component.

Osteochondral fractures can occur at the base of the head of the first metatarsal secondary to trauma. However, few descriptions of osteochondral fracture of the first metatarsophalangeal joint have been reported. All of the previously described lesions have been localized to the first metatarsal head, rather than the phalangeal base. A review of the literature failed to reveal any fractures occurring at the base of the proximal phalanx of the hallux [2].

Malunion of a first metatarsal fracture can result in angular, rotational, or shortening of the metatarsal. Dorsiflexory malunions can be caused by poor intraoperative fixation, loss of fixation postoperatively due to premature weight bearing, or catastrophic failure. There is a paucity of literature on the rate and incidence of malunions following first metatarsal fractures treated either operatively or nonoperatively. The treatment course for a malunion depends upon patient's symptoms, which may include pain, difficulty with ambulation, and transfer metatarsalgia [4].

Central Metatarsal Fractures

The central metatarsals consist of the second, third, and fourth metatarsals. Each metatarsal consists of a head, neck, shaft, and base. The head of each metatarsal articulates with the base of the corresponding proximal phalanx. The neck serves as the junction of the epiphysis and the diaphysis. The diaphysis is the largest segment of the metatarsal. The bases of the second and third metatarsals articulate with the middle and lateral cuneiform respectively. The fourth metatarsal articulates with the medial articular surface of the cuboid.

There are differing opinions on the importance of open reduction and internal fixation for lesser metatarsal fractures. There is little emphasis placed on performing open reduction and internal fixation of displaced central metatarsal fractures. There are a variety of fracture patterns which affect the

J. Randolph Clements (✉)
Carilion Clinic Orthopaedics, Virginia Tech Carilion School of Medicine, 3 Riverside Circle, Roanoke, VA 24014, USA
e-mail: jrclements@carilionclinic.org

M.S. Lee, J.P. Grossman (eds.), *Complications in Foot and Ankle Surgery*, DOI 10.1007/978-3-319-53686-6_10

Fig. 10.1 AP radiograph demonstrates central metatarsal fractures that exceed the acceptable criteria for non surgical treatment

central metatarsals, but the majority of fractures involving the metatarsal head or neck are treated nonoperatively. The plane of deformity is paramount in making this decision. Patients with significant transverse plane deformity can have satisfactory results with nonsurgical care. However, sagittal plane displacement is less acceptable. Rockwood and Green's reported greater than 3–4 mm of displacement or 10° of sagittal plane deformity should be treated aggressively to avoid a painful plantar keratosis and metatarsalgia [5, 6] (Fig. 10.1).

Complication of these injuries can result in osteochondral defects, avascular necrosis, or more commonly sagittal plane malunion. Osteochondral injuries are often caused by axial load, and the cartilage surface sustains a shear-type injury. The majority of the literature pertains to reconstruction of avascular necrosis. However, several authors have described a variety of applicable treatments for osteochondral defects of the metatarsal head [2, 7–10]. These treatments include debridement, excision, synovectomy, and dorsal closing-wedge osteotomy. The treatment depends on the size of the fragment. If the fragment is small, simple excision is sufficient treatment. If the articular insult is large, excision is not recommended and more advance reconstructive techniques should be considered. Rotational dorsal wedge osteotomies have shown to be an excellent option. These osteotomies use the viable and uninjured plantar cartilage to interface with the base of the proximal phalanx. A dorsal wedge is removed from the metatarsal head, and the viable plantar cartilage is rotated dorsally (Fig. 10.2).

Fixation of osteochondral fractures and these reparative osteotomies present another challenge to the surgeon. If the fixation is inadequate, the potential for avascular necrosis and subchondral fatigue fracture increases [7, 11]. Absorbable pin fixation has improved the surgeon's ability to achieve mechanical stabilization of these injuries. Two crossed absorbable pins provide excellent stability for these revision osteotomies

Fig. 10.2 This image is an intraopertaive depiction of a dorsally based wedge. This wedge is removed in to allow the metatarsal head to rotate cephalad to improved the articulation with the proximal phalgeal base

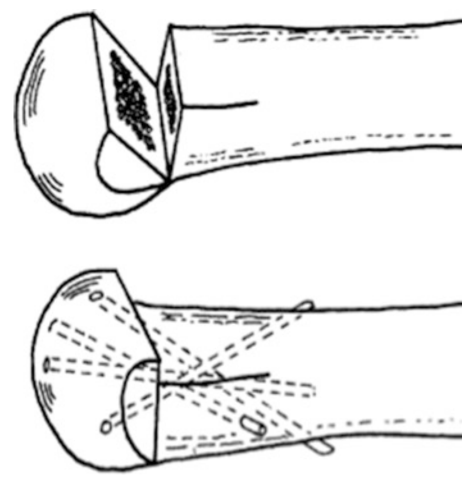

Fig. 10.3 These illustrations show the dorsally based wedge osteotomy in the metatarsal head. This osteotomy allows for dorsal rotation of the articular surface. The second illustration depicts the use of absorbable fixation to stabilize the osteotomy. This illustration shows the dorsally based wedge osteotomy in the metatarsal. This osteotomy allows for dorsal rotation of the articular surface

[7, 9]. Zhongguo et al. reported complete union in all subjects who underwent revision dorsal wedge osteotomy with absorbable fixation [9] (Figs. 10.3, 10.4, and 10.5).

Central metatarsal head malunions and intra-articular metatarsal head fractures are rare. Retroversion of the fracture segment is more uncommon but has been described by Atik [10].

Fig. 10.4 Intraoperative image of fixation technique. The absorbable pins should be placed in a converging orientation. The use of predrill is recommended to simplify the insertion of the absorbable pin. Both steps are shown in this image

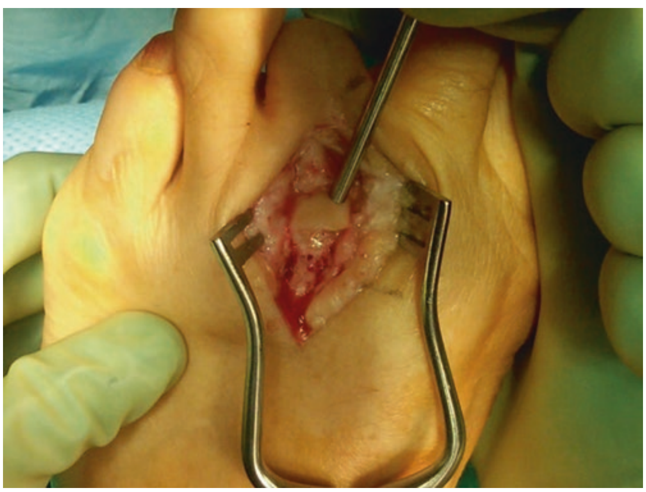

Fig. 10.5 A small tamp is used to recess the pin below the cartilage

Corrective osteotomies for metatarsal fractures have been described in Avian literature [12]; however, this author does not see the clinical relevance in including their findings in this text.

Complications of central metatarsal fractures are usually a result of failure to realign the metatarsal heads and the metatarsal parabola [6]. Corrective realignment osteotomies are used in cases of symptomatic metatarsalgia from malunion. The surgeon should focus on restoration of anatomic alignment for resolution of pain and disability [13]. The surgeon must realize that despite the diligence of restoring the metatarsal parabola, this does not always result in asymptomatic gait.

Fractures of the central metatarsal diaphysis are often treated nonsurgically as well. Certain fracture patterns of the metatarsal shafts are more appropriately treated with surgical stabilization. When the fracture is displaced and surgical treatment is being considered, the pattern of the fracture helps determine the most appropriate fixation. A vertical oriented fracture can be treated in with a 0.062 in. or 0.045 in. retrograde Kirschner wire. Spiral fractures should be stabilized with interfragmentary fixation. The perpendicular placement of this screw is challenging due to inference of the adjacent metatarsals. Because of this, additional dorsal plating is recommended for neutralization. Deviation from this technique can lead to healing complications including nonunion and malunion. Bridge plating works well for comminuted metatarsal shaft fractures. Bridge plating allows the surgeon to "bridge or span" the comminuted segment while concurrently receiving osseous stability from the bone proximal and distal to the area of comminution. This provides stabilization of the fracture without disrupting the biology around the fracture. Another option for stabilizing these fractures is external fixation. This technique is most useful in highly comminuted or open fractures. The surgeon should pay close attention to the metatarsal declination angle when using external fixation. The external fixation bars should be oriented parallel to the long axis of the metatarsal. This will prevent sagittal plane malposition of the metatarsal. Much like metatarsal head malunions, a sagittal plane malunion of the shaft is corrected with realignment osteotomies. When there is a dorsiflexory sagittal plane malunion, the patient will present with symptomatic metatarsalgia juxtaposition to the malunited metatarsal. The treating physician may be tempted to address the symptomatic metatarsal; however, correcting the malunited metatarsal is more prudent. Highly comminuted or segmental fractures of the metatarsal diaphysis can result in painful nonunion. Several techniques have been described to revise these nonunions. The preferred method of revision treatment is intercalary autogenous bone grafting and dorsal plating.

Stress Fractures of the Central Metatarsals

Stress fractures rarely occur due to acute trauma. In most cases the patient has an underlying foot deformity that is aggravated by recurrent and repetitive activity. Other underlying biological issues should be considered as prodromal. These include osteoporosis, vitamin D deficiency, menopause, and obesity. Patients with forefoot pain and stress fracture should also be evaluated for equinus. A tight heel cord can increase the forefoot pressures resulting in stress fracture. This concept is often overlooked as a cause of metatarsal stress fractures. Most stress fractures can be treated nonoperatively. Typically 4–6 weeks in an orthopedic walking boot is sufficient. In some cases, these develop into nonunion and are treated with bone grafting and dorsal plating.

Fifth Metatarsal Fractures

Fractures of the fifth metatarsal are common injuries. Studies have shown that greater than 50% of all metatarsal fractures occur in the fifth metatarsal [14–16]. The majority of these fractures involve the base of the fifth metatarsal, but distal fifth metatarsal fractures involving the head, neck, and diaphysis occur regularly. The decision to operate or treat nonsurgically depends upon the fracture location, angular deformity, and displacement. A moderate amount of transverse plane angulation of the distal fragment is acceptable, but again sagittal plane position of the distal fragment should be carefully scrutinized on the lateral radiograph.

Isolated fractures of the metatarsal head usually occur secondary to a direct trauma. These injuries are typically treated conservatively unless significant sagittal displacement of the head is present. The patient is immobilized in a below-knee cast or fracture boot for 4–6 weeks. If the fracture fails to unite or subsequently displaces enough to become symptomatic, a resection of the fifth metatarsal head can be considered. However, this is not suggested as a primary treatment.

Diaphyseal fractures of the fifth metatarsal are usually a short oblique and oriented proximal- dorsal to distal-plantar [5, 14, 17]. This fracture is commonly referred to as a dancer's fracture. The fracture occurs as a result of ground reactive forces acting distally against a stable proximal metatarsal base. This is often associated with a moderate degree of displacement and shortening due to the obliquity of the fracture. This fracture pattern is more unstable than transverse fractures in the same location. Conservative treatment with short leg casting may be considered if the fracture is well aligned. Open reduction with internal fixation may also be accomplished with the use of small cortical screws or small plating systems (Figs. 10.6 and 10.7).

Fig. 10.6 5th metatarsal diaphyseal fracture showing significant displacement

Fig. 10.7 This picture shows the use of a small cortical interfragmetary screw with a neutralization plate

Comminuted fractures of the fifth metatarsal may also respond well to nonsurgical treatment. In the presence of heavy comminution, achieving mechanical stability of the fracture is often difficult. Bridge plating is very useful in situations of comminution. There are several plating systems available that offer versatile screw orientation.

Fractures of the proximal diaphyseal portion of the fifth metatarsal are often referred to as a "Jones fracture." These are typically caused by an inversion force, creating an avulsion at the base of the fifth metatarsal. A true "Jones fracture" is an acute fracture at the proximal portion of the shaft near the metadiaphyseal junction. If the fracture is treated nonoperatively, reports show up to 66–93% chance of healing [14, 15]. It is important to note that these fractures should be non-displaced. Non-displaced or unicortical fractures should be treated for 6 weeks in a non-weight bearing short leg cast with gradual transition to weight bearing in an orthopedic walking boot.

Traditionally, surgical treatment has been reserved for high performance athletes. However, fractures of the base of the fifth metatarsal should be given careful consideration to all patients due to its limited vascular supply. Because of this, operative management in these fractures may be performed despite significant deformity or displacement. Intramedullary solid screw fixation is recommended. Cannulated screws can be used but do not offer equivocal strength to solid screws. Cannulated screws are less technically demanding. This author recommends using cannulated instrumentation but inserting a solid screw. This is generally achieved by using a standard cannulated guide wire followed by the appropriate cannulated drill bit. After countersinking and measuring, the cannulated guide wire is removed and the appropriate size solid screw is inserted. Since there are minimal discrepancies in drill bit size and outer diameter of the screw, this technique allows the surgeon to use cannulated instrumentation for a solid screw. No statistically significant differences have been reported between titanium and stainless steel.

Smaller avulsion fractures can be treated with tension band wiring. When fracture fragments are too small to accommodate a standard screw, the tension band technique is the best option. The tension band technique is achieved by placing two parallel K wires through the avulsion fracture. Next a pilot hole is drilled in the diaphysis of the fifth metatarsal. An 18- or 20-gauge surgical wire is then used to provide compression and neutralization to the fracture. The use of three small wires to fixate a fifth metatarsal fracture has also been described [17]. This technique allows for a more minimally invasive approach while still providing adequate stabilization. If this technique is used, the surgeon should be conscientious of the orientation of the wires. The wires should be in multiple planes to optimize neutralization.

Fractures of the proximal fifth metatarsal metaphysis (i.e., the Jones fracture) can be problematic because of a high incidence of nonunion and recurrence with nonoperative treatment. In some cases, mainly athletes, reinjury or nonunion can occur despite operative stabilization. This is often attributable to hardware of insufficient strength, aggressive postoperative rehabilitation, or biologic insufficiency at the fracture site (Figs. 10.8 and 10.9).

Hunt et al. recommend revision fixation with a large, solid screw (5.5 mm or larger) with autogenous bone grafting [16]. Additional investigation remains necessary to determine

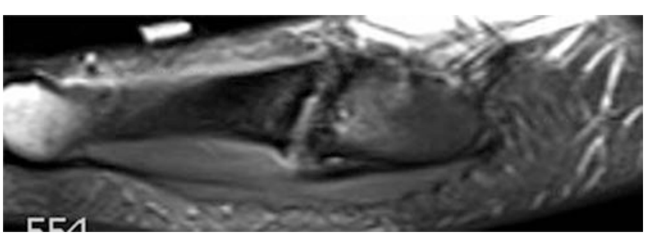

Fig. 10.8 T1 weighted MRI (sagittial and transverse) shows nonunited Jones fracture

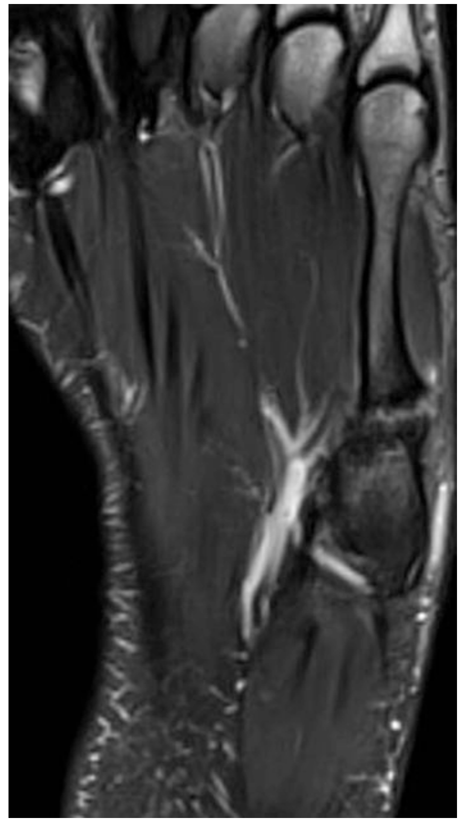

Fig. 10.9 T1 weighted MRI (Tranverse Plane) showing same non-united Jones Fracture

Fig. 10.10 1 year post operative AP foot xrays healed left 5th metatarsal shown previously as non united

Fig. 10.11 AP radiographof the left foot shows nonunited 5th metatarsal with increased fracture gap

Fig. 10.12 Post operative radiographs show internal fixation with autogenous bone graft

Fig. 10.13 1 year follow up showing complete osseous consolidation of autogenous bone graft

whether bone marrow aspirate with demineralized bone matrix is an effective substitute for cancellous autograft [16] (Fig. 10.10).

If nonsurgical treatment results in nonunion and further displacement of the fragment, the treating surgeon may consider autogenous bone grafting. This technique resembles the one previously described in the central metatarsal fracture section. The appropriate size intercalary graft may be harvested from the calcaneus or other locations depending on the defect. The proximal and distal aspects of the bone are debrided to viable margins, and the defect is filled with the autogenous graft. A bridge plate construct is suitable to provide necessary mechanical stabilization [18] (Figs. 10.11, 10.12, and 10.13).

Finally, the exigencies of the athletic and leg-based working population require prompt return to play or work. This need can be met by providing intramedullary fixation as primary treatment. This practice of avoiding the complication of nonunion in this cohort may remain the most prudent treatment of fifth metatarsal metadiaphyseal fractures as it provides better, quicker, and more reliable recovery for the patient [14–16, 18]

Technique Pearls and Pitfalls

Although cannulated instrumentation makes operative treatment of a fifth metatarsal fracture easier for the surgeon, the cannulated design of the screw is weaker than a solid screw. This author supports cannulated screws if the screw is larger than 5.5 mm in diameter. If the screw is less than 5 mm in diameter, a solid screw should be used. Cannulated guide wires, drill bits, and depth gauges can be used if smaller screws are required. However, if the cannulated instrumentation is used, a solid screw should be placed.

Conclusion

In general, complications of metatarsal fractures are unusual. However, given the dynamic mechanical requirement of the first metatarsophalangeal joint, functional need for well-maintained metatarsal parabola, and biologic factors, metatarsal fractures can create challenging clinical scenarios. Since the peer-reviewed literature does not offer a great deal of direction for metatarsal fracture complications, the surgeon should rely on sound surgical principles and an understanding of pedal biomechanics for guidance.

References

1. Root ML. An approach to foot orthopedics. J Am Podiatr Assoc. 1964;54:115–8.
2. Wertheimer SJ, Balazsy JE. A unique osteochondral fracture of the first metatarsophalangeal joint. J Foot Surg. 1992;31(3):268–71.
3. Coker TP, Arnold JA, Weber DL. Traumatic lesions of the metatarsophalangeal joint of the great toe in athletes. Am J Sports Med. 1978;6(6):326–34.
4. Becker A. First Metatarsal Malunion. Foot Ankle Clinic. 2009;14(1):77–90.
5. Tornetta P, Brown C, Heckman JD, McKee M, McQueen MM, Ricci W. Fractures and dislocations of the midfoot and forefoot, rockwood and green. 8th ed. Philadelphia, PA: Lippincott, Williams and Wilkins; 2015. p. 2689–97.
6. Alepuz E, Carsi V, Alcantara P. Fractures of the central metatarsal. Foot Ankle Int. 1999;17(4):200–3.
7. Lee HJ, Kim JW, Min WK. Operative treatment of Freiberg disease using extra-articular dorsal closing-wedge osteotomy: technical tip and clinical outcomes in 13 patients. Foot Ankle Int. 2013;34(1):111–6.
8. Mereddy PK, Molloy A, Hennessy MS. Osteochondral fracture of the fourth metatarsal head treated by open reduction and internal fixation. J Foot Ankle Surg. 2007;46(4):320–2.
9. Zhongguo X, Fu C. Effect evaluation of treating Freiberg's disease with dorsal wedge osteotomy and absorbable pin fixation. Jian Wai Ke Za Zhi. 2009;23(6):651–3.
10. Atik A, Ozyurek S, Cicek EI, Kose O. Isolated slipped-retroverted osteochondral fracture of second metatarsal head. Foot. 2013;23(4):176–9.
11. Capar B, Kutluay E, Mujde S. Dorsal closing-wedge osteotomy in the treatment of Freiberg's disease. Acta Orthop Traumatol Turc. 2007;41(2):136–9.
12. Rahal SC, Teixeira CR, Pereira-Júnior OC, Vulcano LC, Aguiar AJ, Rassy FB. Two surgical approaches to fracture malunion repair. J Avian Med Surg. 2008;22(4):323–30.
13. Murphy R, Fallat LM. Surgical correction of metatarsal malunion. J Foot Ankle Surg. 2012;51(6):801–5.
14. Clapper MF, O'Brien TJ, Lyons PM. Fractures of the fifth metatarsal. Analysis of a fracture registry. Clin Orthop Relat Res. 1995;315:238–41.
15. Zogby RG, Baker BE. A review of nonoperative treatment of Jones' fracture. Am J Sports Med. 1987;15(4):304–7.
16. Hunt KJ, Anderson RB. Treatment of Jones fracture nonunions and refractures in the elite athlete: outcomes of intramedullary screw fixation with bone grafting. Am J Sports Med. 2011;39(9):1948–54.
17. Banks AS, Downey MS, Martin DE, Miller SJ. Metatarsal fractures, McGlamery comprehensive textbook of foot and ankle surgery. Philadelphia, PA: Lippincott, Williams and Wilkins; 2001. p. 1775–90.
18. McBryde Jr AM. The complicated jones fracture, including revision and malalignment. Foot Ankle Clinic. 2009;14(2):151–68.