Closed Reduction and Internal Fixation of Lisfranc Fracture Dislocations

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The success of minimally invasive percutaneous reduction and fixation of tarsometatarsal or Lisfranc injuries lies in understanding the appropriate injury pattern for this method of treatment. The eponym Lisfranc dislocation is derived from injuries sustained to cavalry troops in the Napoleonic era. These were associated with significant vascular and soft tissue injury, as they were treated with an amputation through the tarsometatarsal joints by Lisfranc, Napoleon's surgeon. Although the injuries secondary to equestrian activity have declined, the injury pattern is commonly associated with high-energy motor vehicle accidents, falls, and crushing injuries to the foot [1–4]. These mechanisms typically involve significant bony and soft tissue injury that rarely can be managed by closed methods (Fig. 1). Percutaneous fixation is most amenable in those patients with low-energy mechanisms, particularly in the athletic and elderly populations involving primarily a ligamentous injury (Fig. 2).

Mechanism of Injury

The indirect mechanism associated with the low-energy injury typically results from an axial longitudinal force with rotation on a plantar flexed foot [5–9]. The plantar flexed position of the foot places the weaker dorsal ligamentous restraints on tension, resulting in their failure allowing further displacement and rupture of the plantar ligamentous restraints or metatarsal base fracture [1, 6, 10]. This type of injury may not produce the obvious

Fig. 1 An AP radiograph of a direct injury mechanism with significant displacement and bony comminution that is not amenable to percutaneous treatment

Fig. 2 An AP radiograph of a pure ligamentous injury that is ideally treated by percutaneous methods

clinical picture associated with direct high-energy injuries of severe swelling, deformity, inability to bear weight, and neurovascular compromise [11, 13]. Typical presentation includes swelling throughout the midfoot that improves after 1 week and therefore delayed presentations may not appear to have a significant injury upon visual examination [5]. Persistent pain and tenderness across the midfoot that is aggravated with stress testing of the tarsometatarsal joints is indicative of this injury pattern [12].

Radiographic Evaluation

The radiographic series for a suspected Lisfranc injury should include anteroposterior (AP), lateral, and 30° internal oblique views of both feet. Additionally, external oblique views in both 10° and 20° have demonstrated efficacy in delineating the amount of displacement in the transverse plane [12]. In order to stress the midfoot and demonstrate the injury radiographically, the X-rays should be performed with as much weight bearing as possible. Occasionally, weight bearing is too difficult for the patient, therefore, if the non-weight-bearing X-ray results are normal, repeat weight-bearing views should be performed at 10–14 days [6]. Stress radiographs can be performed to diagnose the instability; however, they should be performed under anesthesia to prevent a false negative finding. The foot is stressed with pronation combined with abduction to detect subtle diastasis or angulation [5, 6, 13]. Coss et al. [14] have shown in a cadaveric model that disruption of the dorsal and Lisfranc ligamentous restraints resulted in a radiographic instability pattern consistently noted on abduction

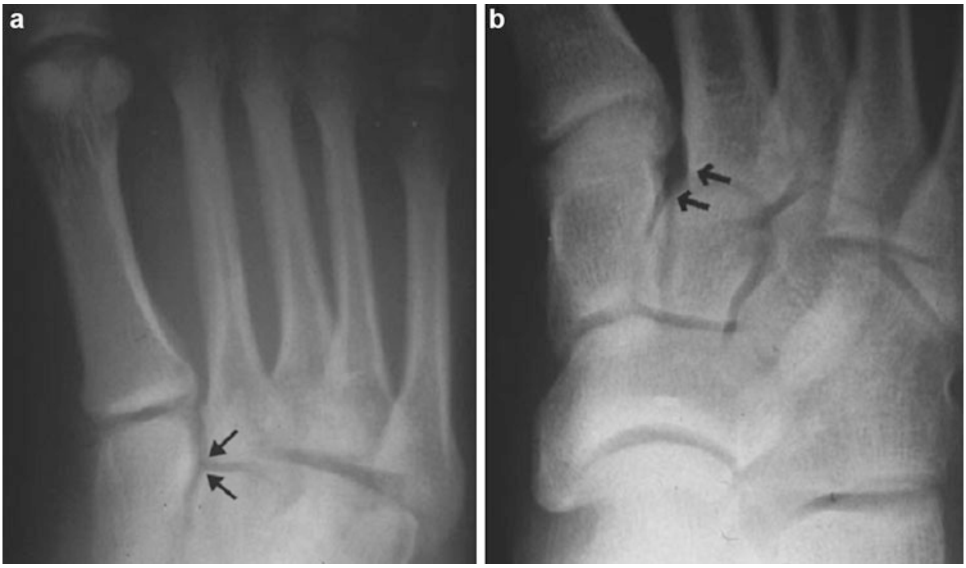


Fig. 3 (**a**) Note that the base of the second metatarsal is in continuity with the medial aspect of the middle cuneiform. (**b**) In a patient with a Lisfranc injury note the lateral displacement of the second metatarsal in relation to the medial aspect of the middle cuneiform

stress examination, verifying the utility of the clinical examination. The anatomic relationships of the tarsometatarsal joints have consistent radiographic appearances; deviations from these patterns are consistent with injury [15]. The medial border of the second metatarsal is in colinearity with the medial border of the middle cuneiform on the AP radiographic exam along with the first intermetatarsal space and the space between the medial and middle cuneiforms (Fig. 3a, b). The lateral border of the third metatarsal is colinear with the lateral border of the lateral cuneiform on the internal oblique radiograph. In addition, the medial border of the fourth metatarsal is colinear with the medial border of the cuboid. Subtle radiographic findings include minor angulation or displacement of the first metatarsal (Fig. 4). Myerson et al. [3] described the "fleck sign," a small avulsion fracture of either the medial cuneiform or the base of the second metatarsal, which is diagnostic of a Lisfranc disruption. Careful review of the radiographs should be performed so that Lisfranc variants with intercuneiform instability are not overlooked (Fig. 5).

Fig. 4 An AP radiograph demonstrating lateral translation of the first metatarsal consistent with a Lisfranc injury

Fig. 5 Note that the diastasis exists between the medial and middle cuneiforms, consistent with a Lisfranc injury, despite the normal relationship between the second metatarsal and the middle cuneiform

Classification

Multiple classification systems exist to describe the injury to this joint complex [2, 3, 16]. The use of the columnar classification developed by Myerson [6, 13, 17] divides the midfoot based on the respective motion segments. The medial column includes the first tarsometatarsal and the medial cuneiform-navicular joints (Fig. 6a). The middle column includes the second and third tarsometatarsal, intercuneiform, and the naviculo-cuneiform joints (between the middle and lateral cuneiforms) (Fig. 6b). The lateral column includes the articulations between the fourth and fifth metatarsals and the cuboid (Fig. 6c). This system of classification has prognostic implications based on the motion of the midfoot. The medial and middle columns have minimal motion (3.5 and 0.6 mm, respectively) and do not tolerate incongruity, suffering the highest incidence of posttraumatic arthritis [17, 18]. Nunley and Vertullo have proposed a classification system to define the midfoot sprain typically seen in athletes [19]. Stage 1 is consistent with pain at the Lisfranc joint without any evidence of diastasis on weight-bearing radiographs. Stage 2 involved 1–5 mm of diastasis between the first and second metatarsal on the AP radiograph, with evidence of lateral

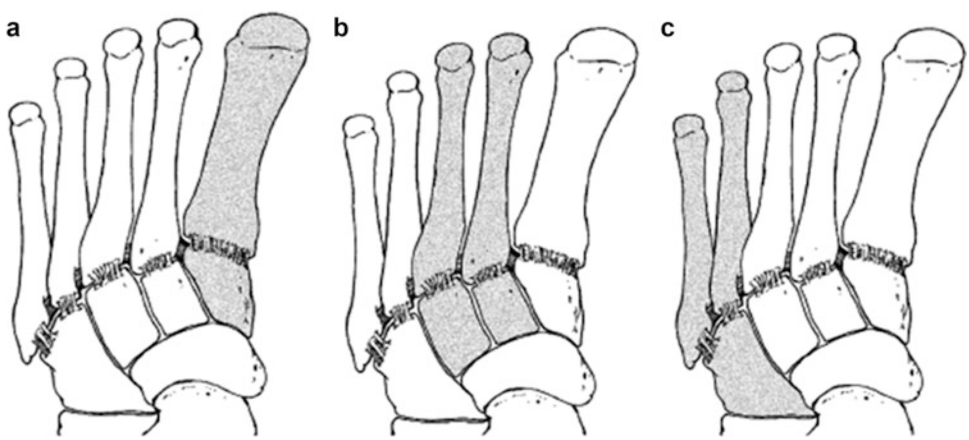


Fig. 6 The medial (**a**), middle (**b**), and lateral columns (**c**) are depicted

arch collapse. Stage 3 is greater than 5 mm of diastasis and loss of midfoot arch height. Patients with stage 1 injuries were successfully treated with a nonoperative treatment protocol that included an initial 6 weeks of a non-weight-bearing fiberglass cast.

Treatment

Although recent literature may suggest that primary arthrodesis offers improved scores at a mean of 42.5 months of follow-up in ligamentous injuries over reduction and internal fixation, the longer-term complications of early arthrodesis may diminish these early results [20]. The current lack of a superior operative treatment method is indicative that treatment may consist of internal fixation or primary arthrodesis of Lisfranc injuries and stage 2 and 3 midfoot sprains via either percutaneous or open approaches. Percutaneous approaches are most amenable for patients with a stress only instability pattern, where the alignment of the midfoot is normal in a non-weight-bearing position. This finding assures the surgeon that an acceptable alignment will be achieved without direct visualization. In patients with poor soft tissue status, vascular disease, neuropathy, or smoking, the use of a minimally invasive technique allows for stabilization of the midfoot while controlling for the risk of wound dehiscence and infection. In these cases, even in the setting of a frank disruption, near anatomic reduction may be preferred over a wound complication. Nonoperative treatment of these injuries is inappropriate as greater than 2 mm of displacement or 15° of angulation is associated with a poor outcome [3].

Surgical Technique

The use of a percutaneous technique requires a thorough understanding of the anatomy of the tarsometatarsal joints and their appearance under fluoroscopy. The undertaking of a percutaneous approach should not be performed unless the surgeon is capable of performing an open reduction, as, on occasion, soft tissue or bony fragment interposition may prevent an anatomic reduction using closed methods. 3.5 mm solid or 4.0 mm cannulated screws are utilized.

Initial attention must be performed to obtaining an anatomic reduction prior to any attempts at fixation. Longitudinal traction is required to reduce the tarsometatarsal joints, and utilization of gauze rolls secured around the phalanges is a powerful aid in reduction (Fig. 7). Initial attention is paid to the medial column, which provides a stable post to which the middle column is reduced. The reduction maneuver involves grasping the hallux firmly and placing a medial- or lateral-directed force to the base of the metatarsal to

Fig. 7 Use of the gauze roll to create phalangeal slings to provide longitudinal traction and aid in closed reduction of the deformity

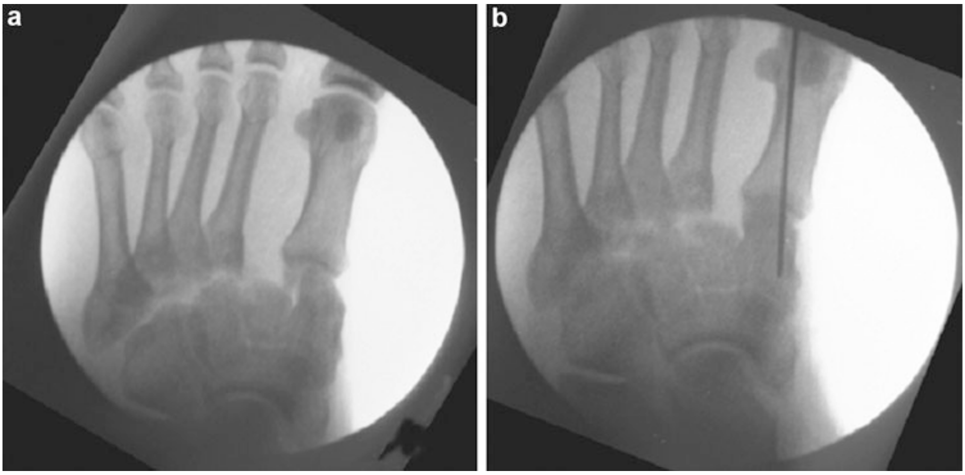
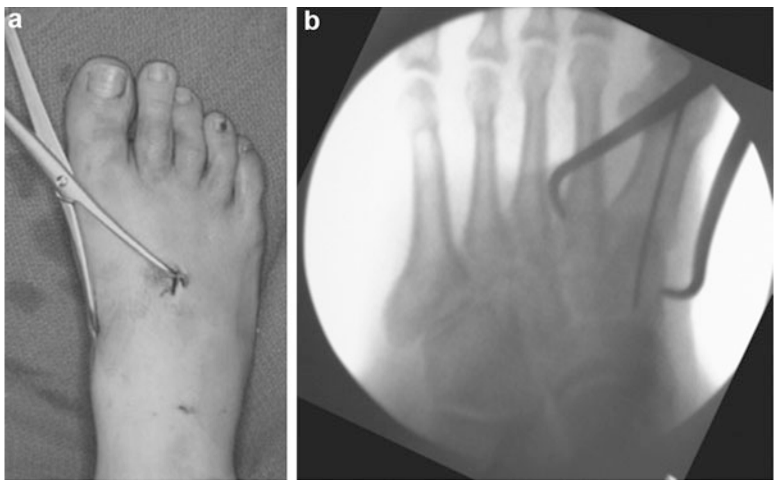


Fig. 8 Lisfranc injury with displacement (**a**) and after closed reduction with provisional fixation of the medial column (**b**)

Fig. 9 Clinical (**a**) and fluoroscopic (**b**) depicting of the use of the bone clamp to reduce the base of the second metatarsal into the mortise



reduce the deformity. Once an anatomic reduction is achieved, provisional fixation is achieved with a guidewire for a cannulated screw (Fig. 8a, b). A screw is placed if appropriate reduction has been achieved. In this case, a fully threaded screw is utilized. A large bone clamp facilitates reduction of the second metatarsal into the mortise (Fig. 9a, b). If persistent diastasis remains despite adjustment of the clamp, then conversion to an open reduction should be performed. Typically, this realigns the third and fourth metatarsals into an anatomic position. A fully threaded screw is then placed obliquely from the medial cuneiform to the base of the second metatarsal. In cases where the third TMT requires stabilization, placement of a screw from the proximal lateral third metatarsal into the middle cuneiform is performed. The guidewire should begin midway between the proximal metatarsal and the metatarsal head with regard to the entry position in the skin. The wire should be placed as parallel to the foot as possible to ensure a neutral position. A partially threaded screw of appropriate length is then placed in order to aid in reduction as it can be very difficult to clamp across this joint. Stability of the lateral column is assessed fluoroscopically and, if persistent instability exists, stabilization is performed with either a 1.6-mm K-wire (Fig. 10).

Fig. 10 Final view of the foot after closed reduction and fixation

If K-wire fixation is utilized for the lateral column, subcutaneous placement is important to prevent infection and premature removal.

Postoperative Rehabilitation

Initial immobilization is a below knee posterior plaster splint to decrease swelling and enhance wound healing. Early mobilization and range of motion are encouraged and rigid fixation with screws is important to prevent loss of reduction. Removal of the splint at 2 weeks is followed by placement into a removable boot, although non-weight-bearing is continued for 6 weeks. Patients are allowed to begin range of motion and strengthening in a pool at 4 weeks and stationary biking is allowed at 6 weeks. Transition to full weight bearing in a removable boot is allowed at 6 weeks. Full weight bearing is allowed at 12 weeks, with conversion to an athletic shoe with a carbon fiber plate orthotic. Hardware removal is typically performed between 4 and 5 months, after which aggressive rehabilitation is performed under the direction of a therapist. Single plane running is initiated at 20 weeks and cutting sports are allowed at 24 weeks. In cases of poor soft tissue, vascular disease, neuropathy, smoking, or heavy labor, the screws may be left in place to decrease the risk of late diastasis. Although leaving the hardware in place may carry the risk of screw breakage, this risk is balanced by avoiding infection and late diastasis. In a healthy individual, screw removal is appropriate to avoid the complications of hardware failure and further articular injury.

Summary

Disruptions of the tarsometatarsal joints can lead to significant disability if misdiagnosed and undertreated. Detailed review of weight-bearing radiographs of the affected extremity and a thorough understanding of the normal anatomic landmarks will consistently lead the clinician to diagnose of even subtle injuries to the midfoot. Percutaneous treatment of these injuries is a very appropriate option in select patients as it avoids the risk of wound complications and morbidity associated with extensile incisions. However, if any question of malreduction exists, conversion to an open reduction must be performed.

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