

Lisfranc Injuries: Anatomy, Diagnosis, Treatment, and Outcomes

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ABSTRACT

Lisfranc injuries refer to a bony or ligamentous injury to the first and second tarsometatarsal and intercuneiform joint complex of the foot. Injuries can be due to low or high energy mechanisms and range from stable injuries to complex fracture dislocations. Additionally, there is a large spectrum of fixation methods from nonoperative management to open reduction and internal fixation or primary arthrodesis. The purpose of this article is to review the anatomy, presentation, diagnosis, treatment, and outcomes of Lisfranc injuries.

Key words: Lisfranc; Lisfranc Injury; Tarsometatarsal fracture dislocation; TMT joint

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INTRODUCTION

The Lisfranc joint is a term used to describe the tarsometatarsal (TMT) joint complex in the foot. This injury was first described by Dr. Jacques Lisfranc (1790-1847), a French surgeon and gynecologist who served in Napoleon Bonaparte's army. Additionally, he was also the first to describe amputations at this level of the foot which would typically occur due to a soldier being knocked from their horse while the foot was still constrained in the stirrup^[1]. Lisfranc injuries are relatively uncommon at 0.2%, but approximately 20% go undiagnosed which can lead to significant morbidity in patients^[2,3]. Up to one-third of these injuries are sustained in low energy mechanisms with the remainder occurring secondary to higher mechanism loads to the TMT joint such as falling from height, crush injuries, or motor vehicle collisions (MVC)^[4-6]. However, Stodler et al. demonstrated from their review the incidence of high energy injuries may not be as high as previously thought (31%)^[7]. The most common mechanism described is a longitudinal axial force applied to a hyperplantarflexed foot^[8]. Men are reportedly more likely to sustain a Lisfranc injury compared to females with a ratio of 4:1^[9].

Diagnosis has improved over the years, mainly due to clinical suspicion as well as improvement in advanced imaging with computed topography (CT) and magnetic resonance imaging (MRI)^[10-12]. Timely diagnosis and treatment are imperative in patients due to the sequela and morbidity of this injury^[13]. Different methods of stabilization including arthrodesis versus open reduction internal fixation (ORIF) for these injuries are heavily debated in orthopedic trauma communities. The following is a current concepts and review of anatomical relationships, clinical assessment, radiographic diagnosis, and treatment alternatives of Lisfranc injuries.

ANATOMY

The Lisfranc joint is a complex combination of ligamentous and osseous relationships that serve to fortify the transverse arch of the foot. This combination is composed of each of the five metatarsals and their corresponding articulations with the medial, middle, lateral cuneiforms along with the cuboid. This commonly referenced “Roman arch” or “transverse arch” provides inherent stability to the TMT complex and midfoot^[14]. The keystone of this arch is found within the second TMT joint. Its recessed nature enables the second metatarsal to articulate with 5 surrounding structures. Hence, the structural integrity of the second TMT joint is vital to biomechanics of the foot^[15].

The transverse metatarsal ligaments are anatomically oriented at the base of the second through fifth metatarsals, but such ligamentous relationships are not seen between the first and second metatarsals. The ligamentous complex between the medial cuneiform and second metatarsal base is composed of three separate ligaments as described by de Palma *et al* and Sripanich *et al*^[16,17]. These three ligaments consist of the dorsal ligament, plantar ligament, and oblique interosseous ligament (Lisfranc ligament). De Palma describes the Lisfranc ligament as up to 10 mm wide and 6 mm thick. Additionally, it has been proven biomechanically to be the strongest of the three ligaments when stressed to failure^[16,17]. The dorsal oblique ligament is the weakest of this complex^[18,19]. Therefore explaining the mechanism of injury. The sequence of failure begins with dorsal ligament, followed by disruption of the plantar ligament, ultimately concluding with the Lisfranc ligament^[17]. Having a clear understanding of the anatomical relationship and biomechanical strengths of this complex is vital to accurately diagnosing and ultimately treating these serious injuries.

PRESENTATION AND DIAGNOSIS

Approximately 20% of the patients with Lisfranc injuries are undiagnosed due to the variations in presentation varying from sprains and minor subluxations to fracture-dislocations of the TMT joint^[20]. The mechanism of which these injuries occur can be categorized into indirect or direct trauma. In regards to indirect trauma, it is a low energy injury that can be frequently seen in athletes^[20]. As previously mentioned, this occurs when the foot is plantarflexed and an axial load is generated across the foot, causing the weaker dorsal ligaments to be disrupted^[21]. Subsequently, either a fracture of the metatarsal base or a rupture of the plantar capsule occurs, which inevitably leads to dorsal displacement of the metatarsal base^[20]. Although the presentations of a low energy Lisfranc injury may not be obvious, it is still important to recognize that failure to treat will lead to post traumatic arthritis from altered biomechanical loading of the TMT joint.

Higher energy Lisfranc injury resulting from direct trauma can be more easily detectable as they often present as fracture dislocations affecting the TMT joint. These injuries are usually seen with mechanisms involving motor vehicle accidents, fall height (greater than 3 meters), and crush injuries^[7]. As previously discussed, disruption to the TMT joint has a wide presentation, therefore a high index of suspicion is required when evaluating a patient with a midfoot injury presenting with pain with weight bearing and swelling. In addition, a very pertinent clinical exam finding is plantar ecchymosis. This clinical finding is often representative of the significant soft tissue disruption^[22].

The first imaging modality to obtain, like with any other suspected

injury, is plain radiographs, which in this case is anteroposterior, oblique, and lateral of the foot. There are five radiographic parameters that are often evaluated in the diagnosis of Lisfranc injuries^[23,24]. First, the medial border of the second metatarsal should align with the medial border of the the middle cuneiform (Figure 1). Next, the medial margins of the fourth metatarsal and cuboid should be well-aligned on the oblique radiograph. The dorsal cortices of the metatarsals should align with the cortices of the articulating cuneiforms and cuboid on the lateral radiograph. A distance greater than 2 mm between the medial cuneiform and the base of the second metatarsal on nonweightbearing imaging is suggestive of Lisfranc injury. Lastly, the presence of a bony fragment in the space between the medial cuneiform and second metatarsal represents an avulsion fracture of the base of the second metatarsal or medial cuneiform and is often described as the “fleck sign”^[25]. The fleck sign is pathognomonic for disruption of the Lisfranc ligament. Although there are these classic signs, injuries can often be missed on plain radiographs.

Another radiographic finding that can help determine if a Lisfranc injury is present is a stress view. The abduction stress radiograph is performed by holding the hind foot while abducting and pronating the forefoot. An anteroposterior radiograph is taken to assess for any instability between the first and second TMT joints^[26]. When able to be performed, the abduction stress view has demonstrated qualitatively greater displacement when judging instability compared with weight bearing views^[27]. Overall, Rankine *et al.* demonstrated radiographs correctly identified 68.9% of Lisfranc injuries when compared to advanced imaging^[23]. If there is a high clinical suspicion for a lisfranc injury, standing weight bearing radiographs can be obtained and compared to the contralateral side to help delineate subtle injuries^[24,25].

Although there are these classic signs, injuries can often be missed on plain radiographs. Rankine *et al.* demonstrated radiographs correctly identified 68.9% of Lisfranc injuries when compared to advanced imaging^[23]. If there is a high clinical suspicion for a Lisfranc injury, standing weight bearing radiographs can be obtained and compared to the contralateral side to help delineate subtle injuries^[23,28].

Myerson *et al.* classified Lisfranc injuries based on direction of dislocation or instability, location, and congruity of the joint^[29]. This classification describes the dislocation as homolateral, divergent or isolated. A homolateral dislocation occurs when the first through fifth metatarsals dislocate laterally or when the first metatarsal remains congruent and the second through fifth metatarsals dislocate laterally. A divergent dislocation occurs when the first metatarsal dislocated medially and the second through fifth metatarsals dislocate laterally. Lastly, an isolated dislocation occurs when only one or two metatarsals dislocate. There is a large spectrum of Lisfranc injuries which can often affect the treatment of these injuries.

Additionally, a computed tomography (CT) scan can further assist in diagnosing a Lisfranc injury, whether initial plain radiographs are negative or further delineation of the injury is required^[23,28]. It is a great complement to the conventional radiographs, as it provides excellent visualization of bony anatomy and subtle details otherwise not seen. Renninger *et al.* demonstrated that patients with high energy trauma to the TMT joint were more likely to be evaluated by a CT scan and less likely to have stress radiographs^[28].

In the presence of negative plain radiographs and CT imaging, the next appropriate imaging modality would be a magnetic resonance imaging (MRI), if clinical suspicion still persists. MRI is the gold standard when trying to identify ligamentous abnormalities, as well as



Figure 1 This image shows a displaced ligamentous Lisfranc injury.

determining the stability of the TMT joint^[10]. In a study by Raikin *et al.*, they were able to come across a sensitivity of 90% for assessing the stability of the Lisfranc joint when compared to intraoperative finding^[10]. Ultimately, the management of Lisfranc injury is dictated by joint stability and proper diagnostic tests are needed to prevent any unwanted morbidity.

TREATMENT AND OUTCOMES

Lisfranc injuries, depending on the severity of the injury, can be managed both nonoperatively and operatively with different treatment modalities available. Regardless of fixation type and injury severity, the goal of nonsurgical and surgical management is to provide a pain-free, stable midfoot that will allow ambulation without complication^[30]. Achieving anatomical alignment is crucial to restore midfoot stability^[31]. Whether or not these injuries are managed conservatively with non-surgical treatment or surgical intervention, multiple factors also need to be considered including articular damage and surrounding soft tissue injury that will also greatly affect the treatment outcome.

Nonsurgical intervention for Lisfranc injuries is dependent



Figure 2 This image shows a healed, fixed bony Lisfranc injury with a comminuted fracture of the base of the 2nd metatarsal.

on a multitude of factors. A thorough physical and radiographic examination in concordance with external patient factors must be all considered when determining surgical versus nonsurgical intervention for these injuries. Watson *et al.* discusses a stepwise protocol and the necessary parameters to determine whether Lisfranc injury can be managed surgically versus nonoperatively^[32]. These parameters include the physical examination, radiography, MRI, CT, and stress examination. When definitive treatment for these injuries is nonsurgical, a CAM walking boot is utilized with the patient allowed to weight bear as tolerated^[32].

It is well agreed that conservative management is indicated for these stable, non-displaced tarsometatarsal joint injuries and one can expect good results. In a study by Nunley *et al.*, 100% of young athletes with stable Lisfranc injuries treated conservatively had excellent results with full return to sport in 3-4 months^[33]. Additionally, Shapiro *et al.* reported good results in 9 athletes who sustained Lisfranc injuries, 8 of which were treated conservatively^[34]. McHale *et al.* looked at Lisfranc injuries in National Football League players and found a trend for earlier return to play in athletes treated conservatively compared to those treated operatively^[35]. The most important factor in the success of non-operative management of these injuries is accurate clinical and radiographic diagnosis of a stable tarsometatarsal joint.

Outcomes of Lisfranc injuries range from fair to excellent^[20].

Disruption of the TMT junction^[21] represents a significant injury, and many have agreed that maintenance of anatomic alignment Lisfranc injuries is a must for maximizing function and outcomes^[33,36-39], as good to excellent outcomes are reported in 85% to 93% of patients with anatomic reduction^[20]. However, there continues to be disagreement regarding which surgical treatment is best for these injuries. Patients can have poor outcomes with chronic pain and disability even with proper diagnosis and treatment^[37]. This is clouded further due to a relative lack of midterm and long-term clinical data reporting outcomes for patients who undergo operative fixation for Lisfranc injuries.

Unstable Lisfranc injuries, whether frankly obvious or very subtle injuries that require further radiographic and clinical evaluation, are managed surgically to restore anatomic alignment and stability^[31]. There are different surgical treatment modalities that have been well established in the current literature for fixation of unstable Lisfranc injuries whether purely ligamentous or fracture-dislocation. Surgical management is indicated for unstable Lisfranc injuries; however, there continues to be controversy over which technique is best given the high incidence of posttraumatic arthrosis and chronic pain despite anatomic reduction^[36]. This has led multiple authors to suggest primary arthrodesis as a preferred treatment for these injuries and multiple studies have yielded good results in low-energy injuries^[12,40,41].

Primary open reduction internal fixation has been the recommended treatment for most unstable Lisfranc injuries^[31,32,36,40-42]. ORIF allows direct visualization of the TMT joints that will allow for improved anatomic reduction, which have been shown to poorly tolerate any malalignment^[42]. A dorsal incision is commonly used directly over the involved TMT joint for direct visualization. Depending on the severity of the injury and joints involved, stabilization of the 1st, 2nd, and 3rd TMT joints is often required^[32]. Fixation is with screws alone or in combination with plate constructs and are used to achieve anatomic reduction and rigid fixation (Figure 2)^[41]. Fixation can be achieved with 3.5mm transarticular cortical screws to achieve absolute stability^[32]. One theoretical benefit of plate and screw constructs is that it avoids further joint damage leading to accelerated arthritis of the tarsometatarsal joints. Alberta *et al.* showed, in a cadaveric study, that both transarticular screws and dorsal plates demonstrated similar adequacy in reduction as well as resistance to shearing across the TMT joint with a weight-bearing load^[43]. If there is instability of the lateral two metatarsals, open or closed reduction and percutaneous pinning is recommended with removal of the wires after adequate healing has occurred^[44]. This allows for the lateral column to remain mobile and allows for more normal gait mechanics^[44].

The type of Lisfranc injury must be considered when deciding what surgical management to utilize for treatment. There is vast evidence in the literature regarding primary arthrodesis for purely ligamentous type of injuries and comparison studies between open reduction internal fixation versus primary arthrodesis of these injuries. In this treatment, the joint surface is often prepped, and bone graft is placed to stimulate the arthrodesis. Recent studies have pushed for the use of primary arthrodesis in purely ligamentous Lisfranc injuries^[6,8,12,13,31]. Ly and Coetzee performed a prospective study comparing primary arthrodesis and open reduction internal fixation in purely ligamentous Lisfranc dislocations, and it demonstrated favorable outcomes in the short and middle-term periods for the primary arthrodesis group^[13]. Typically, patients post-operatively, are non-weight bearing on the affected lower extremity for 6-8 weeks^[21,45]. Leg casts, splints, and CAM walking boots have all been utilized as protection of the

affected foot^[21]. Physical therapy often is indicated for this group of patients once they are deemed full weight bearing as physical therapy and rehabilitation is vital in restoring gait mechanics and intrinsic foot muscle strengthening^[44].

There have been multiple prospective, randomized controlled trials that have sought to determine outcomes in Lisfranc injuries undergoing open reduction internal fixation as compared to primary arthrodesis^[13,37,40]. In unstable, purely ligamentous type Lisfranc injuries, primary arthrodesis leads to higher AOFAS scores, better maintenance of anatomic reduction, higher return to pre-injury activities, higher patient satisfaction, and fewer complications as compared to ORIF^[13,40].

It has been recommended by Myerson to avoid primary arthrodesis in young athletes because primary arthrodesis may prevent restoration of normal foot function^[38]; however, there have been no studies describing long term consequences of midfoot fusion. Primary arthrodesis may lead to faster return to sport/high level activity. In a level 3 study by Cochran *et al.* of young military patients, primary arthrodesis led to earlier return to full military activity and better fitness test scores after one year in comparison to ORIF^[41]. Lewis *et al.* reserve primary arthrodesis for patients with subacute presentations or in cases of severe articular cartilage^[46].

In a systematic review and meta-analysis by Smith *et al.* comparing ORIF with PA for acute Lisfranc injuries, there was no difference in risk for revision surgery, patient-reported outcomes, or non-anatomic alignment^[47]. They did show an increase in hardware removal for the ORIF group; however, hardware removal is part of the standard protocol for many surgeons who utilize this technique.

Overall, outcomes of Lisfranc injuries range from fair to excellent^[20]. Disruption of the TMT junction represents a significant injury, and many have agreed that maintenance of anatomic alignment Lisfranc injuries is a must for maximizing function and outcomes^[33,40,48-50], as good to excellent outcomes are reported in 85% to 93% of patients with anatomic reduction^[20]. However, there continues to be disagreement regarding which surgical treatment is best for these injuries. Patients can have poor outcomes with chronic pain and disability even with proper diagnosis and treatment^[48]. This is clouded further due to a relative lack of midterm and long-term clinical data reporting outcomes for patients who undergo operative fixation for Lisfranc injuries.

COMPLICATIONS

As stated previously, the most important factor in avoiding the most common postoperative complications is achieving an anatomic reduction. Non-anatomic reductions can lead to post-traumatic arthritis in up to 25% of patients^[40,51]. Open reduction internal fixation can lead to increased hardware removal rates, posttraumatic arthrosis, and subsequent need for fusion^[20]. Although primary arthrodesis is increasingly being used to avoid some of the complications associated with ORIF, it is not without its own disadvantages. Primary arthrodesis can result in ray shortening, malreduction, and associated metatarsalgia^[48].

CONCLUSION

Lisfranc injuries are complex bony or pure ligamentous injuries to the Lisfranc joint. These injuries range from stable injuries or sprains, simple disruptions of the Lisfranc joint to complex fracture dislocations of multiple tarsometatarsal fracture dislocations. Diagnosis is often made by plain radiographs but often CT and MRI

used to help make the diagnosis. Treatment consists of nonoperative management for stable nondisplaced injuries to open reduction and internal fixation or primary arthrodesis. Outcomes of these injuries range from poor to excellent. This review article described the anatomy, diagnosis, treatment, and outcomes of Lisfranc injuries.

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