Chapter

Lisfranc Injury in the Athlete

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Abstract

Lisfranc injuries refer to a disruption or destabilization of the Lisfranc joint complex or tarsometatarsal joint complex. These injuries are relatively rare; however, clinical signs are subtle with the injury diagnosis frequently missed. A delay in diagnosis can negatively impact the patient's outcome with sequelae ranging from post-traumatic osteoarthritis to a dysfunctional foot. Therefore, evaluating midfoot injuries requires a high index of suspicion and thorough examination for a tarsometatarsal joint complex injury to allow for maximal return of function and rapid return to sport. The mechanism of Lisfranc injuries in athletes tend to be relatively low-energy which differs from more common higher-energy injuries such as car accidents. Most importantly, identifying and treating Lisfranc injuries requires understanding of the structural anatomy and stability of the midfoot.

Keywords: lisfranc, midfoot, athlete, sports, tarsometatarsal

1. Introduction

The tarsometatarsal (TMT) joint complex is also known as the Lisfranc joint complex. The Lisfranc joint complex is named after one of Napoleon Bonaparte's field surgeons, Jacques Lisfranc, who described cavalry officer injuries and amputations for gangrene through this joint [1]. Thus, a Lisfranc injury refers to a disruption or destabilization of the bones and/or ligaments constructing the TMT joint complex. These injuries are relatively uncommon, occurring in 1 per 55,000 people yearly, which comprises around 0.2% of all fractures [2]. However on initial evaluation, up to 20% of Lisfranc injuries are estimated to be misdiagnosed or completely missed [3]. A delay in diagnosis can negatively impact the patient's outcome and recovery with sequelae ranging from post-traumatic osteoarthritis to a permanently dysfunctional foot [4]. In athletes, these injuries can prohibit players from sport and potentially hinder them from returning to the same level of performance after recovery. Therefore, evaluating midfoot injuries requires a high index of suspicion and thorough examination for a TMT joint complex injury to allow for maximal return of function and rapid return for athletes to sport.

In this chapter, we will discuss evaluation and workup for Lisfranc injuries as well as non-operative and operative treatment of Lisfranc injuries with its impact on athletes.

2. Anatomy

The Lisfranc joint complex refers to the bony and ligamentous midfoot complex comprised of the cuboid and medial, middle, and lateral cuneiform articulating with the five metatarsal bones [1]. The structure's transverse arch resembles the renowned architectural Roman arch, with the second TMT joint serving as the keystone. This bony organization ultimately provides structural stability like the Roman arch to prevent plantar displacement when load bearing on the foot [5].

There are three longitudinal columns that organize the Lisfranc joint complex: the medial, middle, and lateral columns. The medial column consists of the first metatarsal and navicular-medial cuneiform articulation, and the middle column consists of the second and third metatarsal articulating with the middle and lateral cuneiforms [6]. The lateral column consists of the fourth and fifth metatarsal articulating with the cuboid, middle cuneiform, and lateral cuneiform [7].

The TMT ligaments on the dorsal and plantar aspects stabilize the TMT joints, with the second through fifth metatarsals having both dorsal and plantar intermetatarsal ligaments providing stability between these bones [6]. The first and second metatarsals do not have an intermetatarsal ligament, instead having a dorsal, interosseous, and plantar ligaments bridging the medial cuneiform to the second metatarsal [1, 7]. The interosseous ligament is also known as the Lisfranc ligament and serves as the strongest ligamentous stabilizer between the medial cuneiform and second metatarsal [2]. The dorsal ligament is 4.5 times smaller than the plantar ligament and commonly believed to be the weakest ligament of the complex [7].

In addition to the bony and ligamentous architecture of the Lisfranc joint complex, neurovascular structures and muscle tendons are in close-proximity and important to consider when evaluating and operating on a Lisfranc injury. Between the base of the first and second metatarsals, the dorsalis pedis artery and deep peroneal nerve travel on the dorsal aspect of the foot [8]. If there is dorsal displacement with a Lisfranc injury, these structures could be damaged. The anterior tibial tendon is found attaching to the medial cuneiform and base of the first metatarsal, while the peroneus brevis is found attaching to the base of the fifth metatarsal [2]. These structures can potentially block and prevent injury reduction depending on the injury pattern.

3. Mechanism of injury

In the general population, Lisfranc injuries most frequently occur in higher-energy trauma such as car crashes; however, lower energy-impacts are more commonly the cause of Lisfranc injuries in athletes [9]. These injuries may involve bone fractures or be purely ligamentous. In athletes, injury to the TMT joint complex typically results indirectly when a plantar flexed foot loaded axially with or without rotation causes hyper plantar flexion of the forefoot [10], subsequently causing the dorsal ligaments to rupture. On the plantar surface, the plantar capsule may rupture, or the base of the metatarsal may fracture, resulting in midfoot instability from free movement of the metatarsals dorsally [11]. For example, this injury can occur in an athlete falling onto a plantar flexed foot or in an athlete making a sudden change in direction (i.e. rotation) on a plantar flexed foot. These injuries can also occur from direct forces to the athlete such as a direct crushing force on the midfoot.

4. Diagnosis

TMT joint complex injuries can range from a mild subluxation to fracture-dislocations; thus, patients can present with a variety of symptoms. Most consistently, an injury to the TMT joint complex presents with weight-bearing midfoot pain, which can also be induced by testing the joint with passive pronation-abduction [12]. Another potential sign indicating a Lisfranc injury is midfoot swelling [10]. Plantar ecchymosis of the foot arch suggests soft tissue disruption and should greatly increase the index of suspicion for a Lisfranc injury [13]. A 'positive gap' refers to an increased distance between the hallux and second toe which indicates increased intercuneiform instability and can indicate a Lisfranc injury [4]. Additionally, athletes will typically describe a 'pop' in the foot directly preceding a Lisfranc injury, but this history is not necessary to diagnose an injury to the TMT joint complex [14]. Clinical signs and symptoms combined with an appropriate history and mechanism of the patient's injury warrants further workup and evaluation for a Lisfranc injury.

When there is clinical suspicion of a Lisfranc injury, an initial set of AP, lateral, and oblique X-Rays of the foot should be obtained to visualize the TMT joint. Ideally weight-bearing x-rays are taken because the stress can reveal intra-articular diastasis that can self-reduce when the stress of weight bearing is removed. In Nunley and Vertullo's study establishing their classification system for Lisfranc injuries, half of the athletes with midfoot injuries had normal non-weightbearing imaging [15]. Unfortunately the initial set of injury radiographs are often not weight bearing due to pain in the acute post-injury setting precluding weight bearing on the injured foot. Regardless, there is still utility in assessing non weight bearing x-rays for subtle signs of injury, particularly when they are paired with an x-ray of the contralateral, non-injured foot for comparison. When examining an AP view of a normal midfoot, the medial base of the second metatarsal should align with the medial border of the intermediate cuneiform. In addition, there should be symmetric joint spaces along the medial longitudinal column, particularly at the articulation of the medial column and the base of the second metatarsal. On an oblique view, the medial base of the third metatarsal should align with the medial border of the lateral cuneiform in the absence of injury. If there are any step-offs in these lines, then a Lisfranc injury should be suspected. Radiographic findings of dorsal displacement of the metatarsals, >2 mm diastasis of the space between the first metatarsal-medial cuneiform and second metatarsal when compared to the contralateral side, or > 2 mm of TMT joint subluxation indicate instability to the Lisfranc joint [16]. A small avulsion fracture of the second metatarsal base known as the "fleck sign" suggests a Lisfranc ligament avulsion injury [11].

For subtle injuries where a Lisfranc injury is still suspected given appropriate history, mechanism of injury, signs, and symptoms, a weight bearing AP view of both feet on the same cassette or an AP pronation-abduction stress radiograph can help identify dynamic instability by stressing the tarsometatarsal joint complex (**Figure 1**) [16]. Weight-bearing on a Lisfranc injury can be a very painful experience for the patient. Therefore, it is important to inform the patient the reason for obtaining a weight bearing radiograph, since the pain can inadvertently result in uneven weight distribution across the patient's feet and a falsely negative result [17]. Because of major patient discomfort, these radiographs can be obtained using a nerve block or general anesthesia, but this is rarely performed [16, 17].

Advanced imaging modalities such as computed tomography are helpful after inconclusive initial imaging to evaluate subtle fracture-comminution and subluxations. CT scans can also help with surgical planning to decide between primary

Figure 1.
Bilateral AP X-ray of the feet showing > 2 mm diastasis between the right first metatarsal-medial cuneiform and second metatarsal.

arthrodesis versus open reduction with internal fixation [4]. One pitfall of CT is its static nature without weight bearing which limits its capabilities to help evaluate dynamic stability [9]. Weight bearing CT scan is a newer modality that aims to correct some of the deficiencies of CT scans but these not yet widespread and may be of limited utility in the initial post-injury phase due to pain limiting the patients ability to weight. Magnetic resonance imaging is useful to evaluate subtle soft tissue damage in purely ligamentous injuries and stability of the Lisfranc joint, which is a particularly useful tool in athletes where ligamentous Lisfranc injuries are more frequent compared to the general population [14]. When detecting a plantar Lisfranc ligament injury, an MRI exhibited a 95% sensitivity, 75% specificity, and 94% positive predictive value [18].

5. Classification

There are two leading classification systems for categorizing Lisfranc injuries: the Myerson and Nunley-Vertullo systems [9, 19].

The Myerson classification system is commonly used to provide a standardized approach towards describing high-grade Lisfranc injuries (**Table 1**) [19, 20]. In 1909, Quenu and Kuss created the first Lisfranc injury classification system which was modified in 1982 by Hardcastle et al [13] to describe three patterns: type A or total incongruity, type B or partial incongruity, and type C or divergent [20]. The Myerson classification system further modified the Hardcastle system in 1986, and divided type B and C into types B1, B2, C1, and C2. Type B1 specifies partial incongruity with medial displacement, while type B2 specifies partial incongruity with lateral

Myerson	Type description	Nunley-vertullo	Stage description
Type A	Total incongruity	Stage I	No displacement with positive bone scan
Type B1	Partial incongruity with medial displacement	Stage II	Diastasis without a loss in arch height
Type B2	Partial incongruity with lateral displacement		
Type C1	Divergent pattern with partial displacement	Stage III	Diastasis with a loss in arch height
Type C2	Divergent pattern with total displacement		

Table 1.
Comparison of the Myerson classification system typing and Nunley-Vertullo classification system staging.

displacement. Type C1 specifies a divergent pattern with partial displacement, while type C2 specifies a divergent pattern with total displacement [20, 21]. It is important to note that the Myerson classification system is simply a descriptive tool and does not translate to predicting prognosis or determining direct decisions for treatment [13].

The Nunley-Vertullo classification system is advantageous when compared to the Myerson system in its ability to describe low-grade Lisfranc injuries in athletes (**Table 1**) [19]. In addition to its usefulness in athletes, this classification system aids in clinical management by staging the injury and recommending non-operative versus operative treatment depending on the stage. Stage I describes a nondisplaced midfoot with a positive bone scan, which is the only stage that is recommended to be treated non-operatively. Stage II describes diastasis without a loss in arch height, and stage III describes diastasis with a loss in arch height. Injuries graded stage II or III warrant operative management [15]. When it is unclear if a Lisfranc injury is a Nunley-Vertullo Stage I versus Stage II, an MRI can help evaluate the Lisfranc ligament to determine the stage and subsequent treatment plan [22].

6. Treatment

6.1 Non-operative

In patients where there is no evidence of displacement, diastasis, or instability on weightbearing radiographs, their Lisfranc injury is stable [11]. These patients are classified as Stage I using the Nunley-Vertullo classification system and can properly be managed non-operatively [15]. A short-leg cast or a walker boot with protected weightbearing as tolerable for 4–6 weeks is the initial treatment, and weight-bearing radiographs 2 weeks from the injury should be obtained to ensure there is no displacement [6, 17]. If pain persists, a walker boot with weight-bearing permitted can be used for an additional 4 weeks [4, 13]. Stage I Lisfranc injuries can take patients anywhere from 8 to 16 weeks to recover [11]. Despite athletes having to spend a couple of months away from sport, Nunley and Vertullo report that there is a 93% patient satisfaction with this treatment [15]. Therefore, it is important to inform athletes of the recovery timeframe and patient satisfaction at the beginning of treatment before they can return to sport to ensure treatment adherence.

6.2 Operative

Stage II and stage III Lisfranc injuries are unstable and require operative management to achieve reduction [15]. In instances of severe dislocations or compartment syndrome, the injury should be quickly addressed to prevent further complications via reduction or compartment release, respectively [11]. Otherwise, surgical intervention should be delayed 10 to 14 days to allow the soft tissue to heal [4, 16].

In predominantly ligamentous injuries, interosseous transarticular solid screw fixation is thought to be best at holding a reduction to allow the ligament to heal [11]. There is debate whether primary arthrodesis or open reduction with internal fixation (ORIF) yields better results long term for patients with primarily or purely ligamentous Lisfranc injuries in terms of maintaining reduction, degree of deformity, and rate of re-operations [23, 24]. Some surgeons prefer ORIF as a primary treatment choice with primary arthrodesis reserved as a salvage procedure, in cases of late presentation, or in cases of severe articular damage [6, 11]. However, Ly and Coetzee found in a randomized clinical trial that primary arthrodesis has better short and medium-term outcomes than ORIF in primarily ligamentous injuries [25]. It should be noted that ORIF may require a greater reoperation rate when compared to primary arthrodesis, and some studies suggest that there is no statistically significant difference in physical functioning between the two surgeries [23, 24, 26]. With either approach, achieving anatomical reduction and stable fixation should be the ultimate goal [6, 9, 11, 23, 24]. Reduction can be defined as a < 2 mm intercuneiform distance, $<15^{o}$ TMT angle, and absent metatarsal displacement in the dorsal or plantar planes [5]. In the athlete population, it is important to consider athletic performance and restoring midfoot stability; there may be some exceptions in young highly active athletes where ORIF might be considered over primary arthrodesis [13]. These authors prefer ORIF as an operative treatment for athletes.

6.3 Post-operative

Post-operative management for ORIF and primary arthrodesis are the same with non-weightbearing for 6 weeks after surgery, suture removal 2 to 3 weeks post-operation, short-leg cast or boot for 3 to 4 weeks, then weightbearing with arch support insert in a boot, and eventual transition to normal shoes 3 months after the operation [2, 11]. In high performing athletes, pool therapy can be initiated after wounds have healed, and after 4 weeks, stationary bike without resistance can be started [11]. At 12 weeks, running with modified shoes is allowed without cutting or sprinting for another month, then the athlete can gradually return to sport [11]. Screws and plates except inter-cuneiform screws for proximal or medial column injuries after ORIF are removed 4 to 6 months after surgery if there is no radiographic evidence of remaining instability, and athletes should avoid contact sports for 6 to 8 weeks after hardware removal [11, 14].

Regardless of reduction and fixation choice, recovery from Lisfranc injuries largely depends on the degree of instability at the TMT joint [12]. Furthermore, the most common complication from a Lisfranc injury is post-traumatic arthritis which depends on the quality of reduction and amount of articular damage present [24]. A majority of athletes will be able to return to sports after a period of recovery and rehabilitation [27–29], with athletes sustaining ligamentous injuries able to return to sport quicker on average than those with bony injuries [28]. It should be noted that athletes may have deep peroneal nerve sensation loss [28], and athletic level of performance usually decreases after returning from injury [29]. Therefore, it is important to inform athletes of all levels that they may not be able to return to high-level sports, and their level of performance can be affected after recovering from a Lisfranc injury.

7. Surgical technique

7.1 Exposure and reduction

After general anesthesia induction, C-arm fluoroscopy is used to examine and demonstrate instability and opening at the Lisfranc joint with foot manipulation when compared to the contralateral side.

After prepping and draping the foot and ankle in a sterile fashion, a 2-4 cm incision is made just laterally to the second metatarsal's lateral border. Fluoroscopy should be used to mark the incision, since being too medial over the second metatarsal shaft is a common mistake. This makes it difficult to work on the metatarsal's lateral border without causing soft tissue stretching or extending the incision. Scissor dissection is carefully performed down to bone with electrocautery to achieve hemostasis. Care is taken to protect any superficial peroneal nerve branches, and the extensor hallucis brevis is bluntly retracted medially to protect the neurovascular bundle.

The soft tissues are elevated from lateral to medial towards the Lisfranc region, where a portion of the dorsal Lisfranc ligament may be visualized running obliquely from the medial cuneiform to the second metatarsal. These oblique fibers may be homogenous and lacking direction in a scarred, chronic injury or disrupted in an acute tear. A Freer elevator is placed in the Lisfranc's articulation and confirmed with fluoroscopy (**Figure 2**). In the instance of a tear, the Freer will pass easily, but it will not normally pass between the medial cuneiform and second metatarsal. Likewise, intercuneiform disruption can be assessed since the freer should not be able to pass between the medial and intermediate cuneiforms. In the presence of intercuneiform instability, a bridge plating construct can address this issue separately. After an isolated ligamentous Lisfranc injury is confirmed, debris is removed from the joint, and any bridge plating for TMT subluxations can be performed.

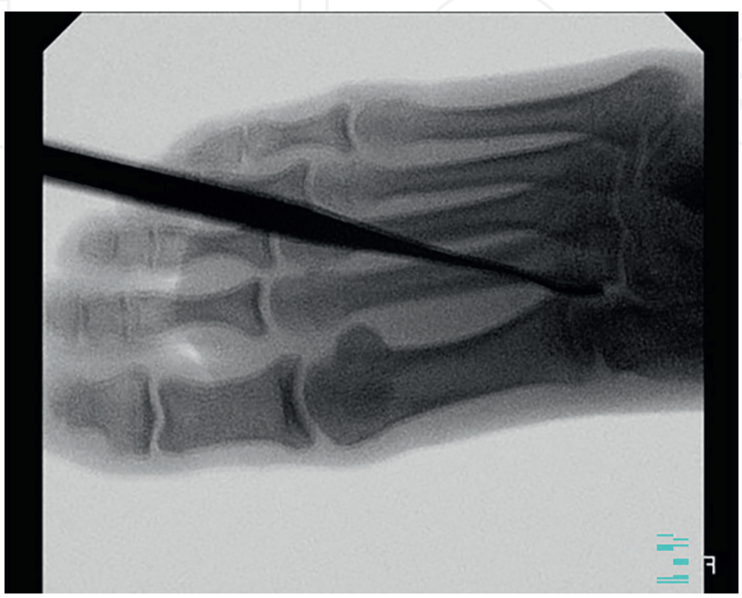

Figure 2.
X-ray of a freer elevator in the Lisfranc articulation.

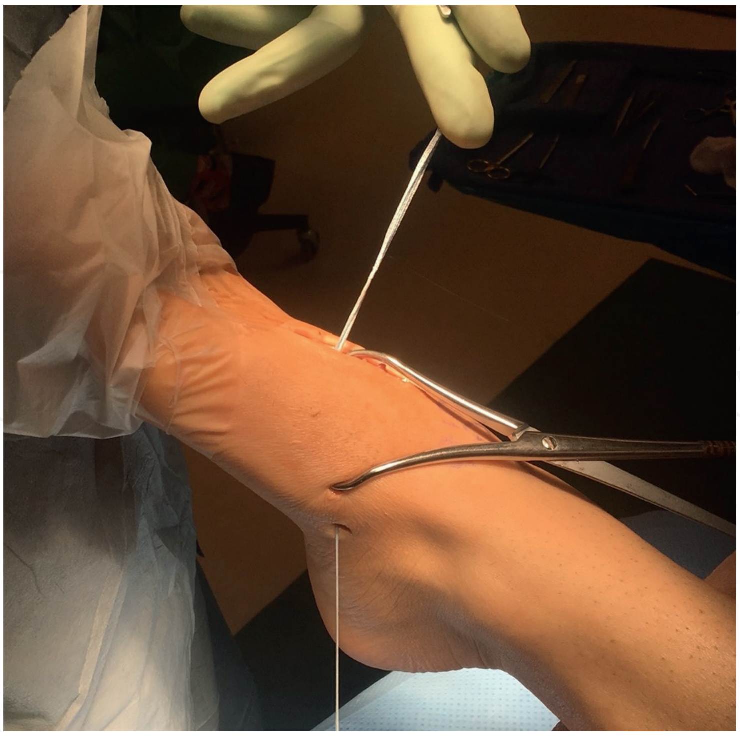

Figure 3.
Lisfranc joint reduction using a large clamp.

Figure 4.
Fluoroscopic confirmation for the Lisfranc joint reduction.

At the border of the medial cuneiform, a percutaneous incision is made. The joint is reduced with a large clamp towards the Lisfranc joint (**Figure 3**) and confirmed using fluoroscopy (**Figure 4**). The TMT joints are evaluated to ensure that joint subluxation was not caused by the clamping.

7.2 Lisfranc repair with *Internal Brace*

Laterally at second metatarsal base just distal to the articulation with the third metatarsal base, a 1.6 mm specialized passing wire is placed. Under fluoroscopic guidance in line with the Lisfranc ligament trajectory, the wire is advanced through the second metatarsal base into the medial cuneiform. The wire's ideal exit point from the medial cuneiform is at the middle from dorsal to plantar, at or just proximal to the bony protuberance often seen on the medial aspect, and plantar and proximal to the obliquely crossing tibialis anterior tendon medially. The wire is continued to be advanced through the medial cuneiform to the medial skin, and a 1–2 cm incision is made to let the wire pass.

A 3.5 mm cannulated drill is placed over the medial portion of the wire to drill approximately 18 mm into the medial cuneiform for the interference screw, with fluoroscopy to confirm that the drill did not violate the medial cuneiform's lateral cortex. If the bone quality is outstanding, the wire is pulled back and a 4.75 mm tap is advanced into the cuneiform approximately 7 mm.

The FiberTape is threaded through a small stainless steel button, then using a passing wire, the 2 mm FiberTape-button construct is passed from lateral to medial. When passing the FiberTape and wire through the bone tunnel, it is important to use the drill's oscillate function. Afterwards, ensure that there is excellent apposition of the small button at the lateral second metatarsal. Pull tightly while diverging the suture limbs away from each other, place a 4.75 × 15 mm PEEK interference screw between the limbs, and advance until the end of the screw is level with the medial cortex.

The clamp is removed, and stability is confirmed under direct visualization by stressing the joint (**Figure 5**). It should no longer be possible to pass a freer into the

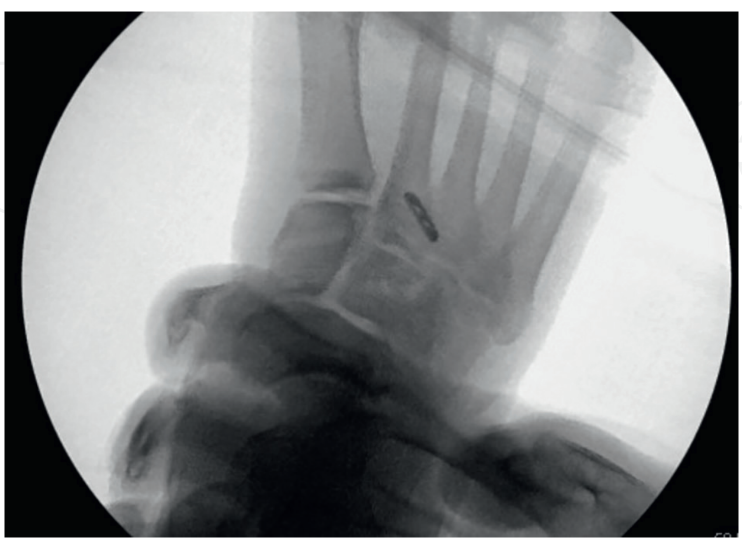

Figure 5.
Confirmation of Lisfranc joint stability under stress.

joint. Fluoroscopy can also be used to confirm the reduction and stability with stress. After irrigating the wound, the incision is closed, and a splint is applied.

Post-operatively, patients are initially kept non-weight bearing with gradual progression of weight bearing sometimes being initiated in the 4–6 week postop period and weight bearing as tolerated often being permitted in the 8–12 week postop timeframe.

8. Conclusion

Lisfranc injuries are relatively uncommon when compared to the frequency of all fractures, but its potentially subtle presentation and severe consequences if missed should make clinicians suspect this injury in patients who present with midfoot trauma [16]. Proper imaging workup with a high index of suspicion is imperative to detect injuries to the TMT joint given the frequency these injuries are misdiagnosed or missed [3]. Stable Nunley Vertullo Stage I Lisfranc injuries can be treated nonoperatively with excellent outcomes, but athletes should be informed of the timeframe for recovery [15]. Unstable Nunley Vertullo Stage II and Stage III Lisfranc injuries should be treated aggressively with ORIF or primary arthrodesis [15]. Understanding the anatomy of the TMT joint complex is essential in operatively treating and stabilizing Lisfranc injuries. For athletes, it is imperative to be honest about treatment outcomes, recovery timeframe, and realistic expected level of play to manage expectations.

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