Lisfranc Injury in the Athlete

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Abstract

» Lisfranc injuries sustained during athletics may be subtle and may be associated with poor outcomes if inadequately identified and treated.

» Accurate diagnosis may involve a combination of weight-bearing radiographs, weight-bearing computed tomography (CT), magnetic resonance imaging (MRI), and/or intraoperative stress examination to determine whether surgical fixation is necessary.

» Nonoperative treatment may be indicated in certain cases that demonstrate radiographic stability with weight-bearing images. A period of non-weight-bearing leads to better outcomes with nonoperative treatment.

» Operative fixation is associated with a high likelihood of full return to sport. Plate fixation may be superior to screw fixation with regard to reduction, risk of arthritis, and need for secondary arthrodesis.

» Open reduction and internal fixation is a suitable treatment option for the Lisfranc injury in the athlete, although successful outcomes and return to athletics are also demonstrated after a primary arthrodesis.

The Lisfranc injury that occurs during athletic activity is typically a different entity than the high-energy Lisfranc injury that occurs after major trauma; often, the radiographic findings are more subtle and patients tend to regain a higher level of function. The athletic Lisfranc injury is a relatively common injury in athletes with midfoot sprains, occurring in 4% of collegiate football players annually, 29% of whom are offensive linemen[1]. When unrecognized, Lisfranc injuries are classically associated with poor outcomes, which is why identification and proper treatment are critical.

Background

Mechanism of Injury

One common mechanism of a Lisfranc injury is forced plantar flexion and/or abduction while the foot is in contact with the ground in an equinus position, although there are many combinations of foot positions that can lead to this condition[2]. A video analysis study of 16 U.S. National Football League (NFL) players with Lisfranc injuries found that 90% occurred while the player was engaged with another player; few were due to direct loading of the foot[3]. A common mechanism identified was a plantar flexed ankle and external rotation force on the foot[3].

Anatomy

The Lisfranc injury is better understood with a closer evaluation of the unique anatomy. The middle cuneiform is recessed 8 mm proximal to the medial cuneiform and 4 mm proximal to the lateral cuneiform, thus limiting translation in the coronal plane[4]. The axial plane is likened to a transverse arch with the middle cuneiform functioning as the keystone. The Lisfranc ligament, or oblique interosseous ligament, is the critical stabilizing structure and runs from the plantar base of the medial cuneiform to the plantar base of the second

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metatarsal. In general, the plantar ligaments of the midfoot are stronger than the dorsal ligaments, and the Lisfranc ligament has been shown to have the highest load to failure[5].

Predisposing Factors

Certain factors may predispose athletes to a low-energy Lisfranc injury. Peicha et al. noted that patients with Lisfranc injuries had a relatively shallower mortise with a less recessed second metatarsal base compared with matched controls[6]. The medial depth was significantly different in the Lisfranc injury group by >2.5 mm ($p = 0.0001$). The length of the second metatarsal was not significantly different between the injured group and the control group. A deeper mortise may allow space for a broader ligament to form, which is therefore less subject to injury. Another study demonstrated a higher risk of Lisfranc injury in patients with shorter second metatarsals compared with overall foot length[7]. As the second metatarsal length decreased in the study group, the risk of Lisfranc injury was increased. Shorter metatarsal length may result in greater pressure on the midfoot leading to a higher risk of Lisfranc injury. Identifying predictive factors may help to reduce the incidence of injury in the athletic population if accommodative orthotics were introduced that compensated for the at-risk anatomy; however, no specific orthotic has been developed or studied to date[7].

Evaluation

Physical Examination and Weight-Bearing Radiographs

Patients typically present with foot swelling and plantar ecchymoses. Manual stress can be performed to assess for instability and an apprehension sign. Pronation and abduction stress under anesthesia can be performed, although this technique is not standardized and is subjective. On weight-bearing anteroposterior radiographs, the medial border of the second metatarsal should align with the medial border of the middle cuneiform. Similarly, on the weight-bearing oblique radiograph, the medial border of the fourth metatarsal should align with the medial border of the cuboid. On the weight-bearing lateral radiograph, the dorsal cortex of the first metatarsal should be collinear with the medial cuneiform. A fleck sign can occasionally be seen and is representative of an avulsion fracture from the medial cuneiform or the second metatarsal base (Fig. 1)[8]. A notch sign has been described that represents medial cuneiform rotation suggesting injury and intercuneiform instability[9]. Weight-bearing radiographs are important in the diagnosis of Lisfranc injury, especially a subtle one. In their series of 15 athletes with Lisfranc injuries, Nunley and Vertullo found that <50% of subtle injuries were detected on non-weight-bearing radiographs[10]. The difference between weight-bearing and non-weight-bearing radiographs was quantified in a series of 9 athletes with Lisfranc injuries; metatarsal base diastasis was noted to be 2.6 mm with weight-bearing and 0.4 mm with non-weight-bearing[11]. Measurements on the injured foot are compared with the contralateral side in any given patient. Weight-bearing radiographs in 100 healthy volunteers and 10 cadavers identified 2.5 mm as the normal distance between the first and second metatarsal bases[12]. Any gap of >3 mm on radiographs should raise suspicion for a Lisfranc injury, according to this study. Although this study indicated a larger gap than is typically considered normal, it is well accepted that ≥2 mm of diastasis between the first and second metatarsal bases is considered an unstable Lisfranc injury.

Cross-Sectional Imaging

Weight-bearing radiographs can be of limited value if the patient is in substantial pain. In the setting of equivocal radiographs and high clinical suspicion (Fig. 2), other modalities such as magnetic resonance imaging (MRI) can be utilized to assist with management decisions[13]. Raikin et al. demonstrated that Lisfranc ligament disruption on MRI was 94% sensitive and 75% specific for intraoperative instability[14]. Based on a series of 21 feet, an algorithm was developed for patients with stable weight-bearing radiographs and clinical suspicion for Lisfranc injury: an intact Lisfranc ligament on MRI is treated nonoperatively, a patient with a partially torn ligament is taken to the operating room for stress examination under anesthesia, and a complete ligament disruption is indicated for surgical fixation.

Fig. 1
Weight-bearing anteroposterior radiograph demonstrating a gap between the medial cuneiform and the second metatarsal base as well as a fleck sign or an avulsion fracture of the second metatarsal base (arrow).

Computed tomography (CT) is another modality that can assist in the decision-making process for a subtle Lisfranc injury. A cadaver study evaluated 6 specimens with Lisfranc disruption and displacement[15]. Radiographs failed to diagnose subluxation in all specimens with 1-mm displacement and in two-thirds of specimens with 2-mm displacement. However, CT accurately identified subtle displacement.

A novel means of evaluating the stability of the tarsometatarsal joint

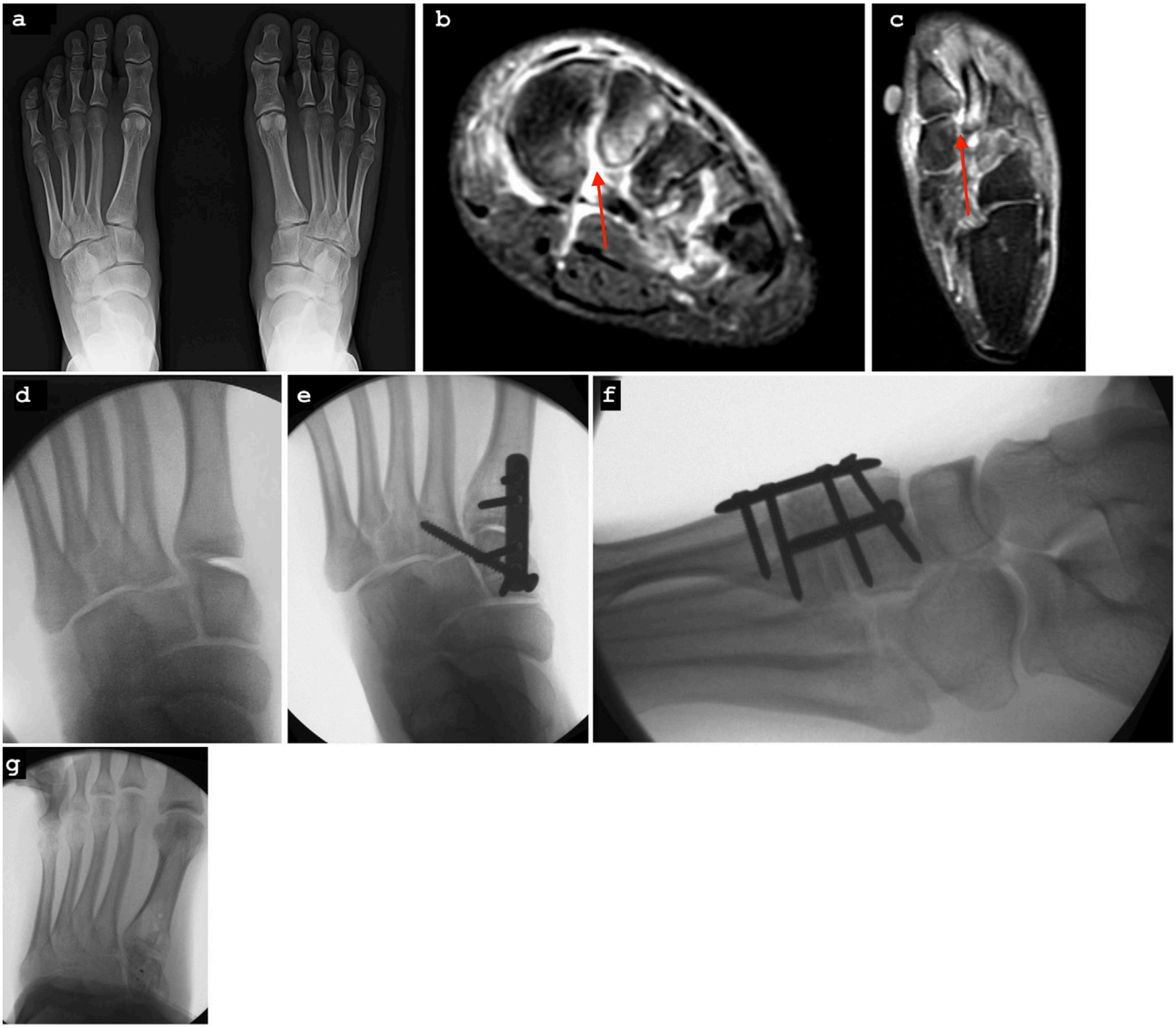

Fig. 2

Fig. 2-A Weight-bearing anteroposterior radiograph of bilateral feet in a collegiate softball player with high clinical suspicion for a left Lisfranc injury. Subtle diastasis between the first and the second ray is suggested on the left foot. **Figs. 2-B and 2-C** MRI was performed and demonstrated complete disruption of the Lisfranc ligament (arrow) as seen on the T2-weighted axial image (**Fig. 2-B**) and coronal image (**Fig. 2-C**). **Fig. 2-D** Fluoroscopy showing the patient after being taken to the operating room and undergoing manipulation under anesthesia; the images demonstrate asymmetry at the first and second tarsometatarsal joints. **Figs. 2-E and 2-F** Intraoperative fluoroscopy, with an anteroposterior view (**Fig. 2-E**) and lateral view (**Fig. 2-F**), after open reduction and internal fixation was performed including a Lisfranc screw and plate fixation across the first tarsometatarsal joint. **Fig. 2-G** Postoperative fluoroscopy showing the foot after the implant was removed at 4 months postoperatively; stress examination under anesthesia demonstrated no further instability.

complex is with weight-bearing CT. Weight-bearing CT has demonstrated utility in evaluating hindfoot alignment and flatfoot deformity[16-22]. However, to our knowledge, no literature exists to date describing the utility of weight-bearing CT in Lisfranc injuries, and the technology has limited availability. Nonetheless, dynamic multiplanar imaging may optimally detect subtle subluxation that is not well defined on weight-bearing radiographs. False interpretation of weight-bearing radiographs is possible because of patient positioning and orientation of the x-ray beam; bilateral weight-bearing CT imaging allows for side-by-side comparison of the injured foot with the uninjured foot to assess for midfoot diastasis without concern for technical error. Similar to weight-bearing radiographs, weight-bearing CT is limited by how much pressure the patient places on the injured extremity. If this is a concern, an ankle block can be performed to reduce pain and improve the utility of the test[10]. In general, diagnosis of a subtle

Lisfranc injury in the athlete is complex and often requires a variety of diagnostic modalities and clinical judgment to determine whether the patient would benefit from surgical intervention. The proposed algorithms for the diagnosis and management of an athletic Lisfranc injury are shown in Figures 3 and 4.

Classification

Quenu and Kuss described the original tarsometatarsal injury classification scheme, which divides cases into 3 types: homolateral, isolated, and divergent[23]. This classification was refined into a more commonly used classification system by Myerson et al.[8]. There are many patterns of injury to the tarsometatarsal joint complex. In athletes, injuries to the intercuneiform space or naviculocuneiform joints are frequently seen. A separate classification was developed by Nunley and Vertullo with the athlete in mind: stage I defines a patient who can bear weight but cannot return to sports despite the absence of radiographic findings[10], stage II is defined as 1 to 5 mm of diastasis between the first and second metatarsals without arch collapse on a lateral radiograph, and stage III is defined as diastasis and arch collapse. This classification does rely on true weight-bearing radiographs.

Nonoperative Treatment

Despite the trend of operative treatment for Lisfranc injuries, some support exists for nonoperative treatment of Lisfranc injuries in the athlete. In a series of 19 athletes with tarsometatarsal joint injuries followed for 2 years, Curtis et al. reported successful outcomes by treating unstable injuries with open reduction and internal fixation and treating stable injuries nonoperatively[24]. Results indicate that those patients with more than a minor sprain who were treated nonoperatively had inferior outcomes; 3 of these patients were unable to return to sport and 1 required a tarsometatarsal arthrodesis within 1 year of injury. Besides inferior outcomes associated with nonoperative treatment of seemingly stable tarsometatarsal injuries, inferior outcomes were also seen in those patients with a delay of diagnosis. In another series of elite athletes with acute Lisfranc injuries, treatment with immobilization and foot-flat weight-bearing for 6 weeks was associated with successful outcomes[11]. Eight of the 9 patients had 2 to 3 mm of diastasis measured on weight-bearing radiographs; 1 patient with 5 mm of diastasis underwent open reduction and internal fixation. The mean time to return to

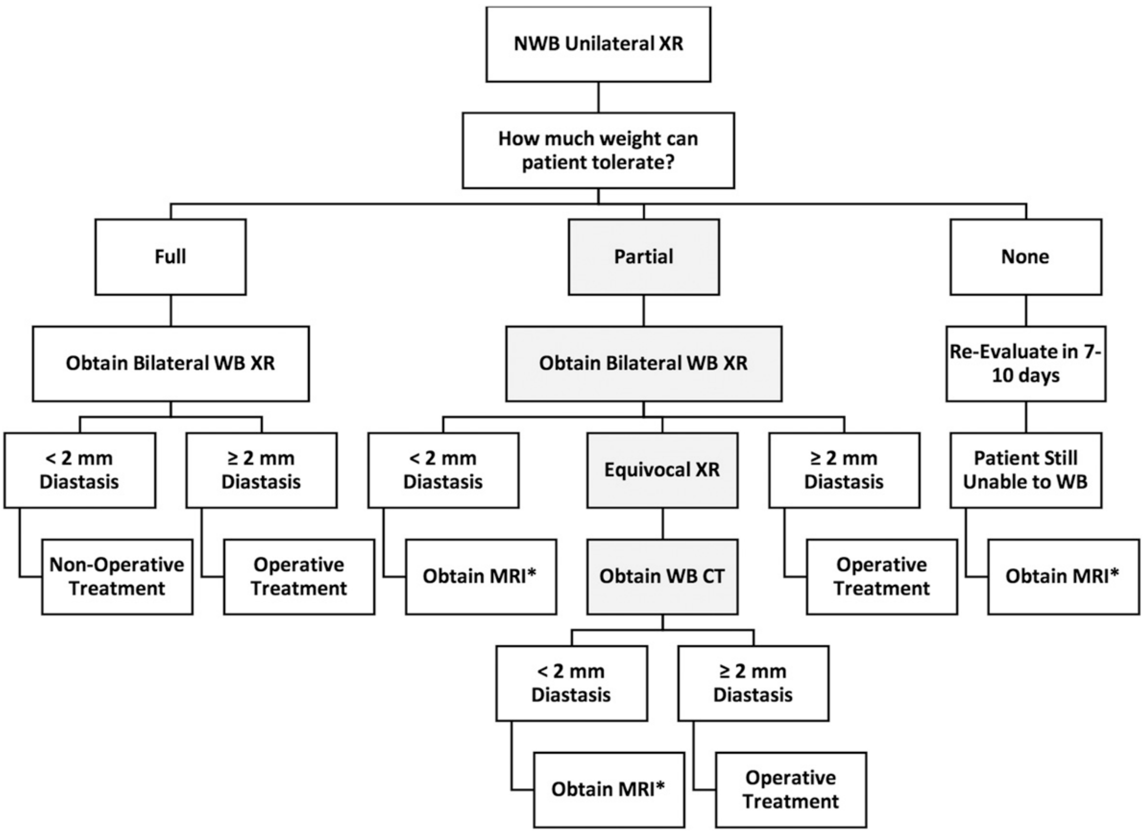

Fig. 3

Novel diagnostic algorithm including the use of weight-bearing CT. Gray boxes indicate common clinical scenarios. The asterisks indicate that the reader should refer to Figure 4 for an algorithm based on the MRI appearance of the Lisfranc ligament. NWB = non-weight-bearing, XR = x-ray (radiograph), WB = weight-bearing, MRI = magnetic resonance imaging, and CT = computed tomography.

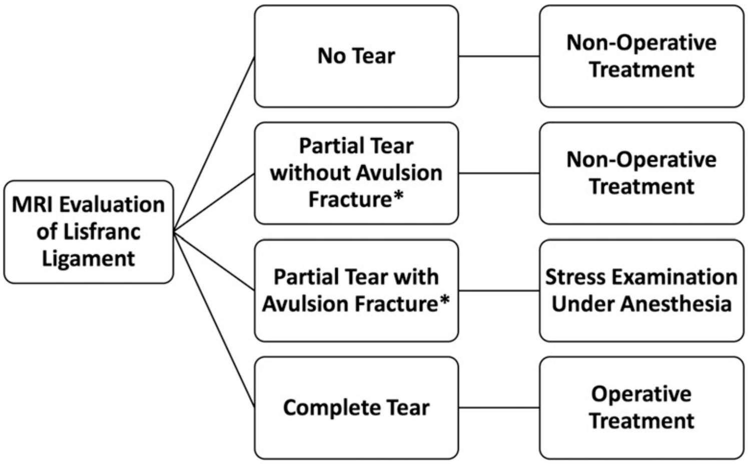

Fig. 4
Diagnostic algorithm based on MRI results as described by Raikin et al.[14]. The asterisks indicate second metatarsal base avulsion fractures.

sport was 14 weeks, with no sequelae after 3 years of follow-up. Although that study supported nonoperative treatment of the subtle Lisfranc injury with displacement in the athlete, most current literature does not report similar outcomes. A combination of operative and nonoperative treatment was used in the series of 15 athletes with 27-month follow-up published by Nunley and Vertullo[10]. Injuries were classified on the basis of weight-bearing radiographs; if the injury was nondisplaced, diagnosis of Lisfranc injury was made using bone scans. Displaced injuries underwent operative treatment with early percutaneous fixation or late open reduction and internal fixation; nondisplaced injuries were treated nonoperatively. Nearly all patients were reported to have excellent results with return to full activity, no pain, and a mean time of return to sports of 14.4 weeks after a surgical procedure and 15 weeks after nonoperative treatment. One patient had a good result although there was a delay in diagnosis of 10 months. This series demonstrates successful nonoperative treatment of nondisplaced Lisfranc injuries, with expected return to sport at around 4 months. An excellent rate of return to sport was also demonstrated after operative treatment. These series have demonstrated successful nonoperative treatment of Lisfranc injuries in the athlete in certain cases[10,11,24], although more recent literature has demonstrated a higher risk of failure[9].

In a series of 36 patients with subtle Lisfranc injuries (<2-mm diastasis on weight-bearing radiographs), patients were initially treated with 6 weeks of weight-bearing as tolerated in a boot[9]. Twenty patients (56%) had persistent pain and inability to return to sports and were indicated for operative fixation using screws or a suture button. Early weight-bearing was permitted at 3 weeks postoperatively and the American Orthopaedic Foot & Ankle Society (AOFAS) score improved to 92 of 100 total points at a mean follow-up of 36 months. The patients who were successfully treated nonoperatively had a final AOFAS score of 75 points, which is suboptimal in a young, athletic population. That study demonstrated a high failure rate of nonoperative treatment of the subtle Lisfranc injury, although patients may have benefitted from a period of non-weight-bearing. That series also showed successful operative treatment after attempted nonoperative management.

Although some cases are described of successful nonoperative treatment of the subtle Lisfranc injury in the athlete, the need for prolonged immobilization and high risk of failure suggest that operative treatment should be considered. Furthermore, displaced midfoot ligamentous injuries are known to lead to arthritis, and the quality of reduction has been shown to be the most important factor for improved clinical results[8,25-27]. To my knowledge, there have been no long-term studies to date evaluating the development of posttraumatic midfoot osteoarthritis after a Lisfranc injury, although studies of patients with high-energy injuries with follow-up of <5 years have suggested that 15% to 30% of patients later develop symptomatic arthritis[8,25-27]. On the basis of current literature, if an athlete presents with an unstable or displaced Lisfranc injury, operative fixation is indicated.

Operative Treatment

Open Reduction and Internal Fixation in Athletes

Successful outcomes have been described after open reduction and internal fixation of Lisfranc injuries in athletes. In a series of 17 professional athletes with acute Lisfranc injuries, 16 patients returned to competition after operative treatment[28]. Most of the 7 ligamentous injuries and 10 osseous injuries were treated with open reduction and internal fixation; 2 comminuted injuries were treated with primary arthrodesis. All patients returned to competition at a mean time of 6 months postoperatively, with the exception of 1 patient with a ligamentous injury treated with open reduction and internal fixation. Patients with osseous injuries seemed to take longer to return to athletic activity; however, this could have been due to a greater severity of injury. Successful outcomes were also reported in a series of 22 athletes with ligamentous Lisfranc injuries treated with percutaneous fixation and early weight-bearing at 3 weeks postoperatively[29]. The AOFAS score was 94 points at a mean time of 33 months postoperatively. In that series of patients, fixation devices were not routinely removed except in 3 patients at 6 months postoperatively without late diastasis. The mean symptom-free time to return to sports was 12.4 weeks. Percutaneous fixation followed by early weight-bearing was associated with high functional scores and a relatively rapid return to athletic activity. Long-term sequelae of leaving the fixation devices in place are not known. A review of a 10-year period in the NFL identified 28 Lisfranc injuries; all but 2 patients returned to competition at a mean time of 11 months[30]. Patients treated nonoperatively returned to sport sooner than those treated operatively, which was likely due to greater injury severity. The data were also difficult to analyze because the timing of the injury during the season was not noted. Performance was analyzed, including total yards and touchdowns for offensive players and tackles for defensive players; no significant change in athletic performance was identified. A trend was noted toward inferior performance over time in the injured group compared with the control group, although this was not significant. Eight patients with Lisfranc injuries treated with delayed open reduction and internal fixation demonstrated good results, with all patients returning to work and previous sports activities; however, the functional scores were inferior compared with those in other studies at 3 years postoperatively[31].

Fixation Method

There is some debate over the fixation method when performing open reduction and internal fixation of a Lisfranc injury. A biomechanical study found no significant difference in joint displacement and resistance to weight-bearing load when comparing a plate construct with a screw construct[32]. Articular damage was quantified at 3% of the joint surface when using a single 3.5-mm screw. A prospective clinical study was performed to evaluate open reduction and internal fixation with plates compared with screws in 60 patients with 31-month follow-up[33]. The implant was routinely removed between 6 and 8 months postoperatively. A small but significant difference was identified in AOFAS midfoot scores at 2 years favoring plate fixation ($p < 0.01$). About the same percentage of patients in both groups returned to preinjury status. Anatomic reduction was achieved in 90% of patients in the plate fixation group compared with 80% in the screw fixation group. More patients in the screw fixation group developed arthritic degeneration seen at the time of device removal. Furthermore, a slightly higher percentage of patients later underwent secondary arthrodesis in the screw fixation group. Although the constructs are biomechanically similar, plate fixation seems to be favored in this series of high-energy Lisfranc injuries.

To my knowledge, no study has formally evaluated the difference between cannulated and solid screws in the fixation of Lisfranc injuries, but solid screws are generally preferred over cannulated screws to reduce the risk of device failure[34,35]. Solid screws are biomechanically advantageous when compared with cannulated screws in other foot and ankle conditions[36,37].

Open reduction and internal fixation using screws or plates has the disadvantage of potentially requiring removal of these devices after an interval of time. The suture button fixation of Lisfranc injuries avoids the need for subsequent device removal and is associated with reasonable outcomes[38]. A biomechanical study demonstrated no significant difference in stability in a cadaver model between suture button and screw fixation, although 1 author disclosed a financial conflict of interest related to the product[39]. Another biomechanical study showed diastasis of about 1 mm with a suture button compared with negligible diastasis with a screw[40]. That study used nearly double the load (61 kg) compared with the previous biomechanical study (35 kg), which is more similar to a patient's full body weight. Seven high-level athletes underwent suture button fixation of a subtle Lisfranc injury after 6 months of failed conservative treatment[38]. At 6 months postoperatively, no patients reported residual deficits. The AOFAS midfoot scores improved from 65 to 97 points. Although that series was small, suture button fixation successfully treats athletes with subtle Lisfranc injuries and avoids the need for subsequent implant removal. Long-term data are necessary to determine whether fixation remains intact or is associated with late diastasis.

Allograft reconstruction of the Lisfranc ligament has been described. A biomechanical study compared allograft reconstruction with screw fixation in 12 cadavers and found no significant difference, although the study was underpowered on the basis of a post hoc power analysis[41]. Five athletes treated with hamstring autograft reconstruction of the Lisfranc ligament showed clinical success, with AOFAS scores improving from 75 to 97 points[42]. All patients returned to previous athletic activity after a mean time of 17 weeks. Long-term data are necessary to determine whether this successful outcome is sustained.

Open Reduction and Internal Fixation Compared with Arthrodesis

Lisfranc injury in the athletic population is typically ligamentous, and treatment of ligamentous Lisfranc injuries is controversial. One of the first studies to suggest that ligamentous Lisfranc injuries may be associated with inferior functional outcomes evaluated a large series of high-energy Lisfranc injuries with a 52-month follow-up[27]. Fifteen of the patients had ligamentous injuries; when compared with combined osseous injuries, functional outcomes tended to be worse in the ligamentous group, and there was a higher rate of posttraumatic arthritis. These differences in findings were not significant, and 44 (48%) of 92 patients were lost to follow-up. Given these findings, a prospective, randomized study compared open reduction and internal fixation with primary arthrodesis in the setting of a ligamentous Lisfranc injury[43]. Forty-one patients were included and had a mean follow-up of 42.5 months. At 2 years and at the time of the latest follow-up, AOFAS scores and visual analog scale (VAS) scores were better in the arthrodesis group than in the open reduction and internal fixation group. Patients who underwent arthrodesis reported that they had returned to 92% of their previous activity level compared with patients who underwent open reduction and internal fixation, who only returned to 65% of their previous activity level. The arthrodesis group had 1 delayed union, 1 nonunion, and 1 compartment syndrome. Fifteen of 20 patients in the open reduction and internal fixation group had loss of correction, worse deformity, or arthritis. Five of the patients later underwent an arthrodesis and, at the time of the report, 2 more patients were scheduled for arthrodesis. Sixteen of 20 patients in the open reduction and internal fixation group had removal of fixation devices at about 6 months, whereas only 4 of 21 patients needed them removed in the arthrodesis group. The follow-up examinations were performed by the operative surgeon, although forms were filled out prior to the patient visit. That study evaluated a group of primarily high-energy injuries that did not necessarily apply to the lower-energy athletic-type injuries, although the results certainly demonstrated successful outcomes with primary arthrodesis for ligamentous Lisfranc injuries.

Another prospective, randomized study included 40 patients with ligamentous and osseous Lisfranc injuries that were randomized to open reduction and internal fixation or primary arthrodesis[44]. At 2 years, functional outcome scores were similar, except for greater upper-extremity dysfunction in the open reduction and internal fixation group with unexplained etiology. The satisfaction rate on a telephone survey at 53 months was 90% in both groups. Patients had similar rates of intermittent nonsteroidal anti-inflammatory drug (NSAID) and assistive device use, and there was a high rate of postoperative employment at the time of the latest follow-up in both groups. The arthrodesis group had 1 nonunion, 1 delayed union, 3 implant removals, and 1 superficial cellulitis. One patient in the open reduction and internal fixation group later underwent arthrodesis and about 80% of patients had implants removed. That study demonstrated successful outcomes with both arthrodesis and open reduction and internal fixation, although ligamentous Lisfranc injuries were not specifically evaluated. Furthermore, the power analysis suggested enrollment of 60 patients, which was not achieved, and only 60% of patients had undergone follow-up at the 2-year mark.

When comparing these 2 prospective, randomized studies, outcomes after open reduction and internal fixation for ligamentous Lisfranc injuries were inferior in the study by Ly and Coetzee compared with those in the study of ligamentous and osseous Lisfranc injuries by Henning et al. (Table I)[43,44]. Henning et al. performed open reduction and internal fixation using 2 screws across the first tarsometatarsal joint, whereas Ly and Coetzee placed a single screw across the joint. Patients were strictly non-weight-bearing for 3 months in the study by Henning et al. compared with 6 weeks of non-weight-bearing in the study by Ly and Coetzee. Subsequently, the patients in the study by Henning et al. had no loss of correction at the time of the latest follow-up, whereas 15 of 20 patients in the study by Ly and Coetzee had a loss of reduction. Screws were not routinely removed in the study by Ly and Coetzee unless symptomatic and 16 of 20 patients ultimately had implants removed. After reviewing these 2 studies, the question arises whether the poor outcome in the open reduction and internal fixation group in the study by Ly and Coetzee should be attributed to the ligamentous nature of the injury or other factors such as fixation method or period of immobilization. Perhaps the apparent benefit of primary arthrodesis in the ligamentous Lisfranc group would be diminished with a more conservative postoperative protocol.

Abbasian et al. performed a retrospective case-matched study of outcomes of open reduction and internal fixation for osseous compared with ligamentous Lisfranc injuries to determine if ligamentous injuries were associated with inferior outcomes[45]. Twenty-nine ligamentous and 29 osseous Lisfranc injuries were included with an 8-year follow-up. All patients underwent temporary open reduction and internal fixation with screws and plates, 3 months of immobilization and gradual, partial weight-bearing, and removal of implants at 3 months postoperatively. Patient groups had similar AOFAS, Short Form-36 (SF-36), and VAS scores. Foot Function Index function and pain were better in the ligamentous group. Seventy-five percent of patients in the ligamentous group returned to baseline level of activity compared with 83% in the osseous group. In each group, 1 patient subsequently underwent arthrodesis. Similar rates of loss of reduction were identified among groups. The authors concluded that ligamentous Lisfranc injuries were not associated with inferior outcomes as compared with osseous Lisfranc injuries after open reduction and internal fixation. Although this study evaluates a group of high-energy injuries, open reduction and internal fixation of a ligamentous Lisfranc injury is associated with successful outcomes.

The functional status after primary arthrodesis for Lisfranc injuries has recently been evaluated. A retrospective study evaluated 25 patients after primary arthrodesis for ligamentous or combined Lisfranc injuries with a 4-year follow-up[46]. The mean AOFAS score was 81 points, and patients returned to about 85% of previous activity levels. Three patients were noted to have adjacent joint arthritis at the time of the latest follow-up. Four patients (16%) had nonunions, 2 of which were treated with

TABLE I Differences Between 2 Prospective, Randomized Studies on Open Reduction and Internal Fixation of Lisfranc Injuries

Differences	Ly and Coetzee[43]	Henning et al.[44]
Type of Lisfranc injuries included	Ligamentous	Ligamentous and osseous
Screw fixation across first tarsometatarsal joint	1 screw	2 screws
Postoperative weight-bearing protocol	Non-weight-bearing for 6 weeks	Non-weight-bearing for 12 weeks
No. of patients with loss of reduction	15 of 20	0 of 14
No. of patients who underwent removal of implant	16 of 20	11 of 14
Functional outcome scores at 2 years		
	AOFAS: 69 points	SF-36: 44 to 54 points
	VAS: 4.1	Short Musculoskeletal Function Assessment: 1 to 23 points
	Returned to postoperative activity: 65%	Satisfaction rate at 53 months: 90%
		Employed: 93%

revision surgical procedures and the other 2 of which were only minimally symptomatic. In a series of 38 patients with primary arthrodesis for Lisfranc injury and 5.2-year follow-up, 75% of patients reported the same or improved level of activities, 45% of which were high-impact activities[47]. Twenty-five percent of patients stated that they were impaired compared with their baseline. The overall satisfaction rate was 97% with respect to return to activities, demonstrating successful outcomes after arthrodesis for a Lisfranc injury.

In an attempt to definitively conclude the optimal surgical technique for Lisfranc injuries, a systematic review and meta-analysis was performed in 2016[48]. A higher risk of fixation device removal was identified after open reduction and internal fixation. No difference was found in the risk of additional surgical procedures, patient-reported outcomes, or loss of reduction between open reduction and internal fixation and primary arthrodesis. That study was limited because of the insufficient literature on this topic to date. Of 1,282 articles identified, 9 were suitable for data usage, and 3 were used in the meta-analysis. The studies attempting to answer this controversial question included many patients with high-energy mechanisms of injury rather than the athletic type of Lisfranc injury that is the focus of this article. At this point, the literature does not support a clear position on whether to fuse or fix a ligamentous Lisfranc injury, although there are certainly favorable outcomes reported for open reduction and internal fixation of a Lisfranc injury in the athlete. In general, primary arthrodesis is not recommended in athletes[49].

Postoperative Management and Return to Sport

Recovery after a Lisfranc injury is highly variable. A summary of postoperative immobilization, time to return to sport, and outcomes shows

TABLE II Postoperative Management and Time to Return to Sport in the Recent Literature

Reference	No. of Patients	Period of Non-Weight-Bearing *(wk)*	Implant Removal *(wk)*	Time to Return to Sport	AOFAS or Outcome	Fixation
Wagner (2013)[29]	22	3	—	12.4 wk	94 points	Percutaneous screw
Crates (2015)[9]	20	3	—	—	92 points	Screws or suture button
Nunley (2002)[10]	8	4	12 to 24	14.4 wk	88% excellent	Screws
Miyamoto (2015)[42]	5	6	—	17 wk	97 points	Autograft
Charlton (2015)[38]	7	6	—	6 mo	97 points	Suture button
Deol (2016)[28]	15	8	16	6 mo	100% return to sport	Screws
Hsu (2016)[49]	—	4	16 to 24	6 to 7 mo	—	Screws

little standardization in management but similar excellent outcomes (Table II)[9,10,28,29,38,42,49]. Some providers initiate weight-bearing as early as 3 weeks postoperatively, whereas others delay weight-bearing for 8 weeks. The time to full return to sport is also variable, ranging from 14 weeks to 6 months. It seems that the longer the patient remains non-weight-bearing, the later his or her return to sport; this could also be related to the severity of the injury. Early weight-bearing should be approached with caution in terms of the risk of early displacement and inferior outcomes. In professional athletes, some authors have recommended implant removal between 4 and 6 months after open reduction and internal fixation followed by up to an additional 8 weeks of limited activities[34,49]. Intercuneiform screws and even the "home-run screw" that travels from the medial cuneiform through the base of the second metatarsal can be left intact to prevent late diastasis[34,49]. Return to sport in professional football has been cited as 6 to 7 months after operative treatment[49]. A series of 8 patients all returned to work and sports after delayed open reduction and internal fixation[31]. Return to sports after arthrodesis is also described between 5 and 12 months[28,30,47,50]. A rigid, molded orthosis with arch support or a carbon-fiber insert is recommended upon return to regular shoewear after a Lisfranc injury, whether treated operatively or not, for a minimum of 6 months[1,2,51,52]. In general, higher functional outcomes and satisfaction are seen in the athletic population compared with high-energy trauma cases. Despite variable surgical techniques and perioperative management, patients with athletic Lisfranc injuries have a high rate of return to function when treated operatively.

Conclusions

Low-energy Lisfranc injuries in athletes can be successfully treated in many different ways. Nonoperative treatment is associated with a high rate of failure. Operative treatment tends to have better outcomes, but whether to treat with open reduction and internal fixation compared with primary arthrodesis is still debatable. New fixation methods such as the suture button may provide adequate fixation for a good functional result while not requiring subsequent removal of fixation devices. Preventive measures can also be investigated to reduce the risk of injury in patients with a shallow mortise. Further study on the low-energy Lisfranc injury in athletes is warranted to determine the optimal type of treatment.

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