Lisfranc Injuries in Sport

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The Lisfranc joint complex is composed of the articulation between the midfoot and forefoot. The joint is named after Jacques Lisfranc de Saint-Martin (1787–1847), a French army field surgeon who described amputation through the tarsometatarsal (TMT) joint, yet did not describe the mechanism of injury or the importance of anatomic reduction following the injury.1,2 Lisfranc injuries have traditionally been associated with high-energy trauma such as motor vehicle collisions and industrial accidents.3,4 Recently, there has been a greater appreciation of midfoot sprains that represent a spectrum of injury to the Lisfranc ligament complex.5 As a result, there has been an increased incidence of such injury resulting from low–energy trauma in activities ranging from recreational activity to elite athletic activity.6 In a study of midfoot sprains in collegiate football players, this injury was found to be the second most-common foot injury, occurring in 4% of players annually. Twenty-nine percent of these injuries occurred in offensive linemen.7 Faciszewski and colleagues6 studied subtle injuries of the Lisfranc joint and found that 60% of patients sustained low-energy trauma (twisting mechanism), with greater than half of these injuries being sports related. Despite being associated with relatively minor radiographic changes, subtle injury can be a source of considerable morbidity in athletes. In one series, three of nineteen patients were unable to return to their sport, and one patient went on to require fusion of the TMT joint.8 Up to 20% of Lisfranc injuries can be overlooked or misdiagnosed based on initial radiographs because of a subtle diastasis. In a case series of 15 athletes who had Lisfranc injuries, 50% (4 out of 8) of the patients that had initial non-weight-bearing radiographs that appeared normal later demonstrated diastasis seen on weight-bearing radiographs.5 An understanding of the anatomy, clinical presentation, and mechanism of injury is necessary to provide appropriate treatment for these injuries.

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EPIDEMIOLOGY

General Trauma

Lisfranc joint injuries are relatively uncommon, accounting for 0.2% of all fractures, with a reported incidence rate of 1 per 55,000 people in the United States annually.\(^9,10\) They are typically the result of a high-energy trauma, such as motor vehicle accidents and falls from heights, and 58% of them are associated with polytrauma. In a review of 76 cases of Lisfranc fractures and dislocations, two thirds were due to motor vehicle collision, with crush injury and fall from a height accounting for the next-largest number of incidences.\(^4\) Vuori and colleagues\(^11\) reported on Lisfranc injuries related to low-energy injuries in 32% of patients, compared with 33% due to high-energy motor vehicle collisions. Almost 40% of Lisfranc fracture dislocations in patients who had polytrauma are not recognized, and 20% are misdiagnosed.\(^12\) This may contribute to the gross underestimation of these injuries, which are most common in the third decade of life, with males being affected two to four times more often than females.

Sport

Midfoot sprains are one of the most common athletic foot injuries, second only to injury to the metatarsophalangeal joint.\(^13\) Direct injury occurs when a crushing load is applied directly to the midfoot. More often, injury is caused indirectly through an axial longitudinal force applied to the foot in a plantar-flexed and slightly rotated position, followed by a forceful abduction, or twisting movement.\(^14\) This is the most common mechanism for Lisfranc sports injuries and has been reported in people involved in soccer, football, gymnastics, horseback riding, windsurfing, basketball, baseball, ballet, and running. Patients often recall an acute traumatic episode associated with a twisting injury to the foot in an awkward position. Ecchymosis extending into the toes and diffuse midfoot swelling may be present. Traumatic dislocation may occur secondary to failure of the weaker dorsal and interosseous ligaments at the TMT joints. People engaged in noncontact sports are also subject to this injury. Women’s gymnastics has been one of the highest injury-producing sports and ranks first among injuries sustained that require surgery.\(^15\) In addition, the ankle and foot are first and third, respectively, in body regions injured in women’s gymnastics. In a series of 14 foot and ankle injuries, five Lisfranc injuries were reported, three that were the result of a fall from the balance beam and two from the vault. The injuries sustained on the beam were due to a direct, traumatic blow from the beam itself. Of these gymnasts, only one was able to return to the sport. In equestrian sports, injuries are the result of forced abduction caused by either falling from the horse with the foot trapped in the stirrup or by having the foot caught between the animal and ground.\(^16\)

Unlike football and gymnastics, Lisfranc injuries are rare in dancers. This may be explained by a combination of internal and external stabilizing forces. In the full-pointe position, the TMT joints are perpendicular to the longitudinal axis of weight bearing, producing more of a compressive force and less of a shear force at these joints. In a dance-related biomechanical study, it was suggested that the stability of the pointe shoe, combined with a high level of training and muscular control in the dancer, provides a protective effect for this type of injury.\(^17\) After sectioning the plantar ligaments in a cadaveric model, a significant improvement in stability during en-pointe loading between the middle cuneiform and the base of the second metatarsal was noted in a comparison of the shod foot and the unshod foot.

Associated Injuries

In addition to classic Lisfranc injuries at the TMT joints, there are other associated injuries or variations of injury. More frequently seen in ballerinas is a unique stress
fracture of the base of the second metatarsal, which is rare in male dancers and other athletes. This suggests that significant force occurs at the base of the second metatarsal during dance that may result in stress fracture. Also, severe abduction forces causing displacement through the Lisfranc joint may result in a “nutcracker” fracture of the cuboid. With TMT dislocation, the cuboid may be crushed between the anterior calcaneus and the base of the fourth and fifth metatarsals. This type of injury can be seen in high-energy motor vehicle accidents, but it has also been reported twice in the medical literature as a relatively frequent pattern in the equestrian pediatric population.\textsuperscript{18,19} The provision of appropriate boots or shoes with smooth soles should be made mandatory in horse riding.\textsuperscript{20}

**ANATOMY**

**Skeleton Description**

The five metatarsal bones contribute to the long plantar arch in the sagittal plane. The TMT articulations transition more proximally in the transverse plane from medial to lateral. In the coronal plane, the base of the second metatarsal is recessed between the medial and lateral cuneiforms to create the classic “keystone” in the shape of a Roman arch, which provides inherent osseous stability. In an imaging study (level III evidence), the mortise of the Lisfranc joint between the medial and lateral cuneiform bones on an anteroposterior radiograph was analyzed. In injured patients, the articulation was significantly less deep when compared with control subjects. It was concluded that the conformation of the bony skeleton provides primary stability, whereas the strong ligamentous and musculotendinous structures provide indirect stability.\textsuperscript{21}

**Ligament Description**

The base of the second metatarsal is connected to each of the cuneiforms by the dorsal ligaments. The plantar and dorsal ligaments are oriented in three different directions: longitudinal, oblique, and transverse. The longitudinal and oblique fibers connect the tarsal bones to the proximal metatarsals. The transverse fibers connect the bases of the metatarsals proximally. Generally, the plantar ligaments are stronger than the dorsal ligaments, which may account for the dorsal direction of dislocations. In addition to the dorsal ligaments, there are two additional ligaments that extend from the medial cuneiform to the second metatarsal base in the coronal plane. There are no interosseous ligaments between the medial and middle cuneiforms. The metatarsal interosseous ligaments are some of the strongest of the ligamentous attachments associated with the Lisfranc joint; however, they are uniquely absent between the bases of the first and second metatarsals. The Lisfranc ligament is located between the medial cuneiform and the base of the second metatarsal. This is the largest of the interosseous ligaments and measures 1 cm in height by 0.5 cm in width.\textsuperscript{22,23} Anatomic studies have demonstrated that it is also the strongest of the interosseous ligaments. In a biomechanical study, the Lisfranc ligament was found to be three times stronger than the dorsal ligaments, providing the most stability, followed by the plantar and dorsal ligaments, respectively.\textsuperscript{24}

**Columnar Theory**

The midfoot can be divided into three columns. The lateral column is the most mobile and consists of the articulation between the fourth and fifth metatarsals and the cuboid. Posttraumatic instability is generally well tolerated in this column, and symptomatic arthritis is rare. The medial column consists of the navicular, the medial...
cuneiform, and the first metatarsal. The middle column is the most rigid, consisting of the second and third metatarsals and their respective TMT articulations.4

The rigidity of the medial and middle columns is essential for the foot to function effectively as a lever arm during normal gait. The Lisfranc ligament links the medial cuneiform to the second metatarsal, rigidly connecting the medial and middle columns while still allowing mobility between the first two metatarsals.25

Range of Motion

The medial, or first column, axis of motion passes through the foot in anterior, lateral, and plantar orientations. It has an inclination of 45° in the frontal and sagittal planes; however, the angle with the coronal plane is not significant, and coronal motion is limited. In the frontal and sagittal planes, there is from 3° to 4° of movement, and dorsiflexion is linked with inversion, whereas plantar flexion is associated with eversion. The lateral column demonstrates increased mobility, with up to 10° of motion in the frontal and sagittal planes. The middle column is the least mobile, given that this region is under the highest forces during the heel-rise phase of the gait.26

Adjacent Anatomy

The perforating branch of the dorsalis pedis traverses toward the plantar area as it passes between the bases of the first and second metatarsals. The deep peroneal nerve follows a similar course and provides sensation to the first dorsal web space. The anterior tibial tendon courses along the medial column and has a broad insertion on the dorsomedial aspect of the base of the first metatarsal and the medial cuneiform. Entrapment of the tibialis anterior tendon has been reported as preventing a closed reduction of the Lisfranc joint.27

CLASSIFICATIONS

Myerson Classification

Historically, the most common classification system used was described by Myerson.4 It is an evolution of the classifications proposed by Hardcastle3 and by Quenu and Kuss.28 Type A injuries represent total incongruity of the TMT joint with all metatarsals displaced in the same plane or direction. In type B1, first ray displacement occurs in relative isolation, in contrast to type B2, in which displacement affects one or more of the lateral four metatarsals in any plane. In type C1, which involves a divergent pattern, the first metatarsal is displaced medially, and the lateral four metatarsals can be in any other concomitant pattern of displacement, seen with partial incongruity. Type C2 represents a divergent pattern with total incongruity. The advantage to this system is a high degree of interobserver reliability to communicate data. This classification does not provide treatment direction or outcome stratification on the basis of fracture patterns and cannot be used to reliably predict clinical results.25,29,30

Nunley and Vertullo5 proposed a classification system that addresses the more-subtle, low-energy injuries seen in athletics. Lisfranc sport injuries classically affect the ligamentous structures and may be associated with small fleck or avulsion fractures. They are primarily soft tissue injuries, and although there is no fracture, injured individuals can suffer tremendous pain and an inability to bear weight on the affected extremity. This classification system guides treatment of the low-energy Lisfranc sprains based on clinical findings, comparative weight-bearing radiographs, and bone scans (Fig. 1).
Stage I is a sprain of the Lisfranc ligament with no measurable diastasis between the medial cuneiform and the base of the second metatarsal or loss of arch height on weight-bearing radiographs. Bone scintigrams will show increased uptake. This injury represents a dorsal capsular tear and sprain without elongation of the Lisfranc ligament. The Lisfranc complex is stable. Stage II sprains result in diastasis of 1 mm to 5 mm between the base of the second metatarsal and the medial cuneiform. The dorsal ligament and interosseous ligaments are injured; however, there is no loss of arch height. Elongation or disruption of the Lisfranc ligament can be present, but the plantar capsular structures remain intact (Fig. 2). Stage III sprains result in diastasis of greater than 5 mm and loss of arch height. This is represented by a decreased or negative value of the distance between the plantar aspect of the fifth metatarsal bone and the plantar aspect of the medial cuneiform bone on a weight-bearing lateral radiograph. This injury may be associated with more-significant displacement, and in such cases, the Myerson classification should be used to describe the injury.

IMAGING

Standard Radiographs

Initial imaging should consist of anteroposterior, 30° oblique, and lateral radiographs of the affected foot. Weight-bearing views should be obtained to provide stress across the injury to check for diastasis caused by ligamentous injury. When weight bearing is limited by pain, ankle block anesthesia can be used. There is no study that defines how much weight is necessary to define a radiograph as a weight-bearing study. Comparison views can also be helpful, provided the contralateral foot is uninjured. Radiographs should also be examined for associated fractures, which occur in 39% of patients who have Lisfranc injuries.
In an uninjured foot, the medial aspect of the base of the second metatarsal should be aligned with the medial aspect of the medial cuneiform on the anteroposterior view. The medial aspect of the fourth metatarsal base should be aligned with the medial aspect of the cuboid on the oblique view. On the lateral view, the dorsal surface of the first and second metatarsals should be level with the corresponding cuneiforms. The most consistent radiographic finding in Lisfranc joint injuries is the loss of alignment of the medial border of the second metatarsal with the medial border of the middle cuneiform. Four additional observation points include (1) the distance between the first and second metatarsal bones, (2) the distance between the medial and intermediate cuneiform bones on an anteroposterior radiograph, (3) the distance between the plantar aspect of the fifth metatarsal and the plantar medial cuneiform bones on a lateral radiograph, and (4) the presence of avulsion fractures (fleck sign). Comparisons should be made with the contralateral foot, and any diastasis that is 1 mm greater than that of structures in the uninjured foot should be considered diagnostic.

**Additional Imaging**

Bone scans are useful for stage 1 injuries and can show minor metabolic and blood flow changes when other imaging modalities demonstrate normal results. Additionally, they may show increased uptake in the region of injury for up to 1 year after the injury or event.

Some authors suggest the use of CT and MRI, however these imaging studies are generally not weight bearing, and in nondisplaced injuries, may provide little additional benefit. CT scans are useful to assess fracture comminution and are more commonly used in high-energy Lisfranc joint injuries. The usefulness of the MRI will depend on the expertise of the physician who is interpreting the films. Raikin and colleagues, compared MRI findings to intraoperative stress radiographs and surgical findings and determined that magnetic resonance imaging is accurate for detecting traumatic injury of the Lisfranc ligament. It is useful to assess Lisfranc joint complex instability when

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**Fig. 2.** Comparison anteroposterior weight-bearing radiograph demonstrating diastasis between the base of the second metatarsal and the medial cuneiform on the right foot.
the plantar Lisfranc ligament bundle is used as a predictor. The appearance of a normal ligament is suggestive of a stable midfoot, and documentation of its integrity may obviate the need for a manual stress radiographic evaluation under anesthesia for a patient with equivocal clinical and radiographic examinations.  

**Stress Radiographs**

Many authors advocate using stress radiographs for both acute and nonacute injuries. Abduction stress radiographs allow the examiner to dynamically visualize the space between the second metatarsal and second cuneiform and the space between the first cuneiform and the second metatarsal and cuneiform (longitudinal). This represents dorsal displacement and might allow visualization of abnormal movement that could lead to posttraumatic arthritis. Subtle first cuneiform–second metatarsal diastasis is difficult to detect using abduction stress radiographs because the direction of the x-ray beam is often too oblique with respect to the joints of interest, resulting in difficulty determining the actual diastasis. The failure to detect a first cuneiform–second metatarsal diastasis may also be the result of dorsal translation of the first cuneiform, which may cause the three-dimensional diastasis to appear more vertically oriented.

**CONSERVATIVE TREATMENT**

Lisfranc joint sprains and fractures should be referred to surgeons who have specific interest either in trauma or in foot and ankle surgery. Nunley and Vertullo stage I sprains can be treated using a non–weight-bearing cast for 6 weeks, followed by the use of custom-molded orthotics. This treatment may be successful for patients who have been misdiagnosed for up to 8 months. If pain continues after cast removal, consider using a removable boot for 4 additional weeks. Some authors suggest conservative treatment for all painful injuries that do not show displacement on stress views. Stress views should be repeated 10 to 14 days after the initial injury. If stability is maintained, treatment should continue for 6 weeks of immobilization in a short leg cast, with the foot in a relaxed, slightly inverted position. Conversion to a removable fracture boot may be possible after 6 weeks, with progressive weight bearing as tolerated. For isolated ligamentous disruptions, the duration of immobilization may need to be 3 to 4 months to prevent displacement. Range-of-motion exercises can be initiated at 6 to 8 weeks. Progressive weight bearing can begin at 3 months, with physical therapy as needed. A molded, cushioned insert with cushioned, supportive running footwear should be used. Communication with the patient plays a central role in the treatment of these injuries. The patient should have a clear understanding that the injury is not a common ankle sprain and that in elite athletes it may result in a prolonged course of recovery after injury.

**SURGICAL TREATMENT**

**Indications**

Nunley and Vertullo stage II injuries should be treated operatively with an initial attempt of closed reduction under fluoroscopy. Screw fixation is preferred, using either partially threaded, cannulated 3.5-mm or 4.5-mm screws (dependent on patient size) or fully threaded, noncannulated screws. In a review of 19 athletes, open reduction and internal fixation was preferred for all patients who had diastasis, regardless of degree, despite the risk of arthritis that may be sustained from an intra-articular
screw. Stiffness is preferred in lieu of instability to provide a rigid lever to the medial column during gait and activity.

Myerson type B1 injuries should be fixed using a screw inserted from the medial cuneiform into the base of the second metatarsal and from the medial cuneiform into the intermediate cuneiform bone. Type B2 injuries should be fixed using a percutaneous screw from the medial cuneiform into the base of the second metatarsal bone.

Open Reduction Internal Fixation Compared with Arthrodesis

The most important goal of surgery for Lisfranc injuries should be the anatomic reduction of the TMT joints. Arthrodesis has been reserved as a salvage procedure after the failure of open reduction and internal fixation, after a delayed or missed diagnosis, or for severely comminuted intra-articular fractures of the TMT joints with a high suspicion of risk for posttraumatic arthritis.

Some authors advocate arthrodesis as the treatment of choice for Lisfranc complex injuries. In one study of 41 patients with primarily ligamentous injury, patients treated using open reduction internal fixation (ORIF) tended to have greater loss of correction, greater deformity, and more degenerative changes than those treated using primary arthrodesis. However, arthrodesis was contraindicated for subtle injuries with minimal or no displacement. Kuo and colleagues also suggested that some patients with purely ligamentous Lisfranc injuries may be better treated using primary fusion. Mulier and colleagues advocated the use of open reduction and internal fixation or partial arthrodesis for severe Lisfranc injuries, and they stated that primary complete arthrodesis should be reserved for cases of severely comminuted fractures or as a salvage procedure.

Lateral Column Treatment

The literature is in agreement on the treatment of the lateral column. When the fourth and fifth TMTs are well reduced, no procedure is necessary; however, when they are not well reduced, percutaneous reduction using Kirschner-wires (K-wires) should be performed, with removal after 6 weeks. The goal is to preserve motion in the lateral column to allow normal gait and to avoid overloading of the lateral column as the result of an iatrogenic stiff foot. Posttraumatic arthritis is rarely symptomatic in these joints.

SURGICAL TECHNIQUE

Regardless of the choice of using osteosynthesis or arthrodesis, the goal is to obtain an anatomic reduction. Fixation is described in three variations. The second metatarsal base is used as a keystone in the first variation. The joint is reduced and held in place using a large, Weber, pointed reduction clamp. The base of the second metatarsal is lagged through the medial cuneiform in line with the normal Lisfranc ligament. After stabilization, if the first metatarsophalangeal joint is unstable, it is fixed using another screw, placed distal to proximal, using either a fully threaded or partially threaded positioning screw. It is important to countersink this screw head to prevent dorsal fracture of the base of the first metatarsal. The third metatarsal is secured to the middle or lateral cuneiform from distal to proximal. Alternatively, each joint is anatomically reduced and provisional fixation is accomplished using wires. Stabilization of each metatarsal to its proximal articulation is then achieved using non-lag screw fixation. A third alternative is commonly used in Europe. In this option, any plantar fragments in the base of the second metatarsal are reduced and lagged from the dorsal aspect of the metatarsal. The TMT joints are then reduced, and non-lag screws are
placed across each of the TMT joints, including the fourth and fifth. The screws are left in place for only 8 weeks, after which all the screws are removed. There is a concern that this technique leads to a higher incidence of late displacement because of the early removal of the screws.\textsuperscript{37}

**TIMING**

The soft tissue envelope is respected, and surgical timing is delayed until the skin wrinkles, indicating that the swelling has subsided. Compartment syndrome is less likely in sports injuries than crush injuries. However, if it is present, fasciotomy is indicated for injuries of the foot.\textsuperscript{25} Prompt diagnosis and treatment may allow for improved outcome and better healing potential.

**SURGICAL APPROACH**

*Longitudinal Incision*

Sangeorzan and Hansen describe the use of two incisions: a straight or lazy-S incision over the second TMT joint and a second incision between the third and fourth TMT joints, with the addition of a third, more-lateral incision when the lateral column is involved.\textsuperscript{41} Alternatively, a more medial incision is made that is deepened through the anterior tibial tendon retinaculum and subsequently repaired at the end of the procedure. The incision may also be extended if an extensive arthrodesis that includes the navicular–cuneiform joint is addressed. The extensor hallucis brevis tendon lies directly over the neurovascular bundle, which is retracted medially. A more-lateral second incision, which is centered over the midfoot, may be used in cases of involvement of the third TMT joint. In cases of lateral column involvement, a third incision, using the interval between the sural and superficial peroneal nerve, allows exposure of the fourth and fifth TMT articulations with the cuboid.

In a meta-analysis, Desmond and Chou\textsuperscript{25} recommended a medial or dorsal incision over the first TMT joint while avoiding the first intermetatarsal space to protect the dorsalis pedis artery and deep peroneal nerve. The second incision is positioned between the second and third TMT joints, and a third incision may be added between the fourth and fifth TMT joints when the lateral column is involved. Arntz and colleagues\textsuperscript{42} suggested placing the medial incision in the first web space, but taking care to create full-thickness skin flaps to protect the dorsalis pedis artery under the skin bridge to prevent necrosis of the skin bridge, and they proposed placing the lateral incision between the fourth and fifth metatarsals. As an alternative, they suggested the Hannover approach, in which the incision is extended from the second web space proximally to the extensor retinaculum. The incision may then be extended proximally towards the knee when necessary.

*Transverse Incision*

Mann and colleagues\textsuperscript{43} noted that wound necrosis and limited access to the TMT joints are two common problems encountered in the approach to the Lisfranc joint. A novel transverse incision has been described as a solution to these problems. The transverse incision lies in a zone of the midfoot that is proximal to the arcuate artery and distal to the lateral tarsal artery. It preserves the dorsalis pedis artery, minimizing the disruption to the midfoot’s cutaneous blood supply. Surgical exposure is performed using six different intervals to gain exposure to the Lisfranc joint. The exposure is ideal when the injury is more severe and involves multiple TMT joints. In a series of 12 patients, wound complications were not seen in patients for whom various forms of immunosuppression were used.\textsuperscript{44}
ARTHROSCOPIC APPROACH

Although uncommon, arthroscopic reduction using five portals has been described. The first is a portal medial to the first TMT joint that allows access to the plantar medial aspect of the first TMT joint. The remaining portals are interosseous and include P1–2 (the junction point between the medial cuneiform and the first and second metatarsals) to explore the second TMT joint; P2–3 (the junction point between the second metatarsal and the intermediate and lateral cuneiforms) for the third TMT joint; P3–4 (the junction point between the cuboid, the lateral cuneiform, and the third and fourth metatarsals) for the fourth and fifth TMTs; and P4–5 (the junction point between the proximal articular surfaces of the fourth and fifth metatarsals).45

AUTHORS’ PREFERRED APPROACH

In the approach preferred by the authors of this article, the patient is placed supine on the operating room table with a calf tourniquet. An attempt at closed reduction under fluoroscopic guidance is performed. A large, pointed reduction clamp is used for the reduction, with the points positioned at the lateral aspect of the base of the second metatarsal and the medial aspect of the medial cuneiform (Fig. 3). If the joint is anatomically reduced, a fully threaded, percutaneous 3.5-mm screw is placed from the medial cuneiform to the base of the second metatarsal. If the joint cannot be anatomically reduced using percutaneous attempts, then an open approach is used. The joint is exposed through the interval between the extensor hallucis longus tendon and the deep neurovascular bundle. The dorsal interosseous ligaments will be visibly torn (Fig. 4). A rongeur can be used to remove tissue that prohibits anatomic reduction (Fig. 5). If necessary, K-wires are used to assist with provisional fixation (Fig. 6). When the joint is anatomically reduced, a guide wire is placed from the medial cuneiform to the base of the second metatarsal and a cannulated drill is used to drill the medial cuneiform only (Fig. 7). Before drilling, a guide pin is advanced through the skin on the dorsum of the foot to prevent the possibility of difficulty in removing a broken guide pin associated with drilling. After the medial cuneiform has been drilled, the guide pin is removed and a 2.5-mm drill bit is used to drill into the base of the second metatarsal. The appropriate-length screw is selected and then advanced from the medial cuneiform to the base of the second metatarsal. Care is
taken to protect the soft tissues to avoid interposition of the tibialis anterior between the bone and screw (Fig. 8). Stability is examined in adjacent joints, and if there is instability between the cuneiforms or at the first TMT joints, these joints are stabilized using screw fixation. Fig. 9 is an anteroposterior radiograph that demonstrates complete reduction of the diastasis in a collegiate lacrosse player.

Fig. 4. Torn dorsal Lisfranc ligaments.

Fig. 5. A rongeur can be used to remove interposed soft tissue.
**FIXATION CHOICE**

**Screws**

Internal fixation has been described using cortical 4.5-mm and 3.5-mm screws with or without lag technique. Some authors support the use of 3.5-mm screws with no lag technique because it presents less risk of arthritis.\(^{39,40}\) Screws across the third TMT joint fail most often. This is most likely caused by the close proximity of the third TMT joint to the more-mobile fourth and fifth TMT joints. Screws across the first TMT joint had the second-highest prevalence of failure. The addition of a second screw from proximal to distal added rotational stability, prevented plantar gapping, and decreased the rate of screw breakage.\(^{41}\)

**Plates**

Plate fixation may minimize intraoperative trauma to the articular surfaces of the TMT joint and theoretically help to improve patient outcome by allowing earlier...
postoperative range of motion. In a study comparing the use of plantar plating to the use of transarticular screws, it was found that plantar plating was stiffer and sustained less displacement from initial to final loading. A biomechanical study demonstrated that dorsal plating resulted in a less stable construct compared with plantar plating, and was comparable to the use of transarticular screws. The primary concern with dorsal plating is soft tissue irritation postoperatively. Newer plate designs with low-profile plates and screw heads have decreased soft tissue irritation.

Fig. 8. Tissues are protected to avoid entrapment of the tibialis anterior tendon.

Fig. 9. Anteroposterior radiograph demonstrating complete reduction of the diastasis in a collegiate lacrosse player.
**Kirschner Wires**

K-wires should be used frequently for provisional fixation or temporarily in cases of severe comminution in which screw purchase is poor. This is the preferred fixation method used for the lateral column to allow for anatomic healing without compromising mobility of the fourth and fifth TMT articulations.

**New Materials**

Bioabsorbable materials, such as polylactide screws, avoid the need for subsequent surgery to remove hardware. In a clinical study, the use of absorbable screws was found to be safe and without reaction, and their use obviated the need for screw removal at short-term follow-up. Biomechanical studies have demonstrated acceptable stiffness in other anatomic regions, such as the tibiofibular syndesmosis, when they were fixed using bioabsorbable screws.

**COMPLICATIONS**

The most common problem resulting from Lisfranc injury is posttraumatic arthritis. Failure to diagnosis the injury or malreduction increases the risk of posttraumatic arthritis. Kuo and colleagues observed a 25% rate of arthritis in their series, and 50% (6/12) of those patients were treated using arthrodesis. Myerson and colleagues, in their largest Lisfranc series (level IV evidence), reported an additional 27 operations on 20 patients at an average of 18 months: 17 of the 27 procedures were performed using arthrodesis. Other procedures that were performed included exostectomy, neuroma resection, tendon lengthening, and skin grafting. Sangeorzan and colleagues treated 16 patients who failed initial treatment using salvage arthrodesis. The deformity was reduced, and lag screw fixation was used to stabilize the arthrodesis. Good to excellent results were achieved in 11 patients, and fair or poor results in 5 (level IV evidence). Although it is important to treat symptomatic arthritic joints, preservation of lateral column mobility achieved by avoidance of fourth and fifth TMT arthrodesis is advised.

Additional complications described included complex regional pain syndrome, symptomatic hardware, injuries to the superficial or deep peroneal nerve manifested as a sensory deficit, hardware failure, incomplete or loss of reduction, deep venous thrombosis, infection, nonunion, and malunion.

**POSTOPERATIVE TREATMENT**

In general, the extremity is placed in a well-padded dressing with a plaster posterior splint or a removable boot until suture removal at 2 weeks. The patient remains non-weight bearing in a short leg cast or boot for an additional 4 to 10 weeks, depending on the injury. For a subtle Lisfranc injury in an athlete, weight bearing may be initiated at 6 weeks using a removable boot and accommodative orthotic. Temporary K-wires are typically removed at 6 weeks and should be removed before weight bearing to prevent pin breakage. Different authors suggest that screw removal may be scheduled from 6 months to 12 months following surgery.

**OUTCOMES**

In the literature, there are no significant differences with respect to outcome for age, gender, and cause of injury. Anatomic reduction and early treatment significantly affect the outcome. Current available level IV evidence demonstrates an American Orthopaedic Foot and Ankle Society score between 68 and 72.
colleagues (in their largest series of 76 patients) and Arntz and colleagues (28 good results in 30 patients, with an average follow-up of 3.4 years) found that the quality of the initial reduction is the most important factor for excellent or good clinical results. When comparing the use of ORIF with that of arthrodesis, Richter and colleagues did not find a significant difference in the method of treatment at an 8.5-year follow-up. They suggested that the restoration of the columns is very important, as reflected by the high correlation between correct column length and good functional outcome. They also suggested that treatment should be dictated by the condition of the soft tissue envelope and that repeated attempts of closed reduction should be avoided. In a case series with follow-up at an average of 30.1 months, Mulier and colleagues found that ORIF demonstrated good or excellent results in 65% of cases, compared with 45% in the arthrodesis group. Nonunion was also present in 33% of cases in the complete arthrodesis group. Reflex sympathetic dystrophy, stiffness in the forefoot, and difficulty in wearing shoes were seen more frequently in patients in the complete arthrodesis group compared with those in the ORIF or partial arthrodesis groups; however, these differences were not statistically significant, and therefore it was concluded that there was no difference in outcomes between the cases using partial arthrodesis and ORIF.

Conservative treatment in athletes who have Nunley and Vertullo stage I Lisfranc injuries is supported by other reported outcomes in the literature. Meyer and colleagues reported on 23 athletic sprains, of which only three demonstrated diastasis. Shapiro and colleagues reported on nine athletes who had type B1 injuries; they treated only one using patient using surgery. Excellent results were reported, with athletes returning to their sport at 3 months. Conservative treatment does not offer a more rapid return to sports when compared with operative management.

**FUNCTIONAL EVALUATION**

In Richter’s series, pedobarographic measurement results correlated with patient subjective outcomes. Only patients who did not have considerable symptoms showed a normal or near normal gait pattern. The results of the gait analysis, using the F-Scan in-shoe pressure monitoring system (Tekscan, Inc, Boston, Massachusetts), as performed by Teng and colleagues, did not show a significant difference between the injured and the noninjured foot in 11 patients.

**SUMMARY**

Lisfranc complex problems represent a broad spectrum of injuries. There should be a high index of suspicion of this injury, and prompt diagnosis is important to allow athletes to return to their sport with the best possible outcome. Nonoperative treatment is reserved for stage I sprains. The goal of operative treatment is to achieve a stable anatomic reduction. In non or minimally displaced injuries, reduction may be performed percutaneously; however, if a perfect reduction cannot be obtained, formal ORIF is recommended. Primary arthrodesis should be reserved as a salvage procedure for complex injuries with intra-articular comminution or significant displacement. A gradual return to athletics with sports-specific training is important to prevent reinjury. Despite appropriate treatment, subjective outcomes may not parallel the radiographic outcomes, and patients should be aware of the severity of the injury.
REFERENCES


