Lisfranc Complex Injuries

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8.1 Introduction

Lisfranc or tarsometatarsal (TMT) joint complex injuries involve disruption of one or more of the osseous or ligamentous stabilizers of the transverse arch of the midfoot [1, 2]. The TMT joint complex encompasses the bases of the first through fifth metatarsals and their respective articulations with the three cuneiform bones and the cuboid bone [3]. The Lisfranc joint is stabilized by dorsal, interosseous, and plantar ligaments that tether the lateral border of the medial cuneiform to the medial border of the second metatarsal base. These three ligaments are collectively known as the "Lisfranc ligament" [3, 4].

Injuries to the Lisfranc or TMT joint complex are generally rare and almost 20% are missed or misdiagnosed on initial imaging [3, 5, 6]. Lisfranc injuries often occur as a result of axial loading of the plantarflexed foot and may involve any of the joints in the TMT complex [3, 7]. Injuries may occur via high- and low-energy mechanisms [3, 8]. However, low-energy mechanisms constitute a significant number of Lisfranc injuries seen in the athlete. Injuries to the Lisfranc joint are potentially career-ending for the athlete, as they often result in significant long-term morbidity such as post-traumatic osteoarthritis, anatomic deformity, and functional disability [1, 3, 8, 9]. Early diagnosis and appropriate management of a Lisfranc injury is therefore essential [2]. While non-operative management is a feasible option for stable injuries, surgical treatment is typically recommended for unstable injuries [8, 9].

The objective of this chapter is to discuss the current treatment options for Lisfranc injuries. However, the literature regarding operative management of Lisfranc injuries is in need of more high-quality, randomized controlled trials before any definitive recommendations regarding optimal surgical techniques can be made.

8.2 Clinical Evaluation

Prior to intervention, a surgeon should obtain a detailed history, with special emphasis placed on the mechanism of injury [10]. Lisfranc injuries can occur in acute traumatic settings from both high- and low-energy mechanisms. In athletes, Lisfranc injuries often present with subtle signs following a low-velocity mechanism [8]. The position of the foot and the direction of force applied at the time of injury are key aspects of the history. Injuries classically occur with axial loading of the foot in a hyper-plantarflexed position [3, 8].

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Medial plantar ecchymosis of the midfoot is a hallmark of Lisfranc injury [8, 10]. Other additional findings include midfoot edema and tenderness to palpation. Passive flexion of the metatarsal (MT) heads as well as passive abduction-adduction through the forefoot may demonstrate instability within the TMT joint. Special tests such as pronation-abduction of the forefoot and the TMT compression test may elicit pain in the injured region of the midfoot [9]. Examination should always include a thorough neurovascular assessment as dislocation of the second metatarsal can compromise blood flow through the dorsalis pedis artery. Additionally, diffuse swelling may lead to compartment syndrome [3, 8, 10].

8.3 Radiographic Evaluation

Weight-bearing radiographs of both the injured and uninjured foot should be obtained in addition to the standard non-weight-bearing AP, oblique, and lateral views of the foot [5, 10]. It is recommended that radiographs include imaging of the ankle, as concomitant injuries may be missed [11].

On radiographic imaging of a Lisfranc injury, there will be intra-articular displacement throughout the TMT joints, the intercuneiform joints, and/or the naviculo-cuneiform joint which is distinct from an uninjured radiograph [10] (Fig. 8.1). Any displacement of more than 2 mm in any plane around the TMT joint should raise suspicion for a Lisfranc injury [8]. The "fleck sign" indicates an avulsion of the second metatarsal base into the interval between the first and second metatarsals. This radiographic sign is pathognomonic of a Lisfranc injury [3, 9, 10] (Fig. 8.2). Additionally, the lateral radiograph may reveal either dorsal or plantar displacement of the affected joints as well as an overall flattening of the medial column [3].

Stress radiographs may be necessary in patients with indeterminate weight-bearing images. Advanced imaging is useful when there

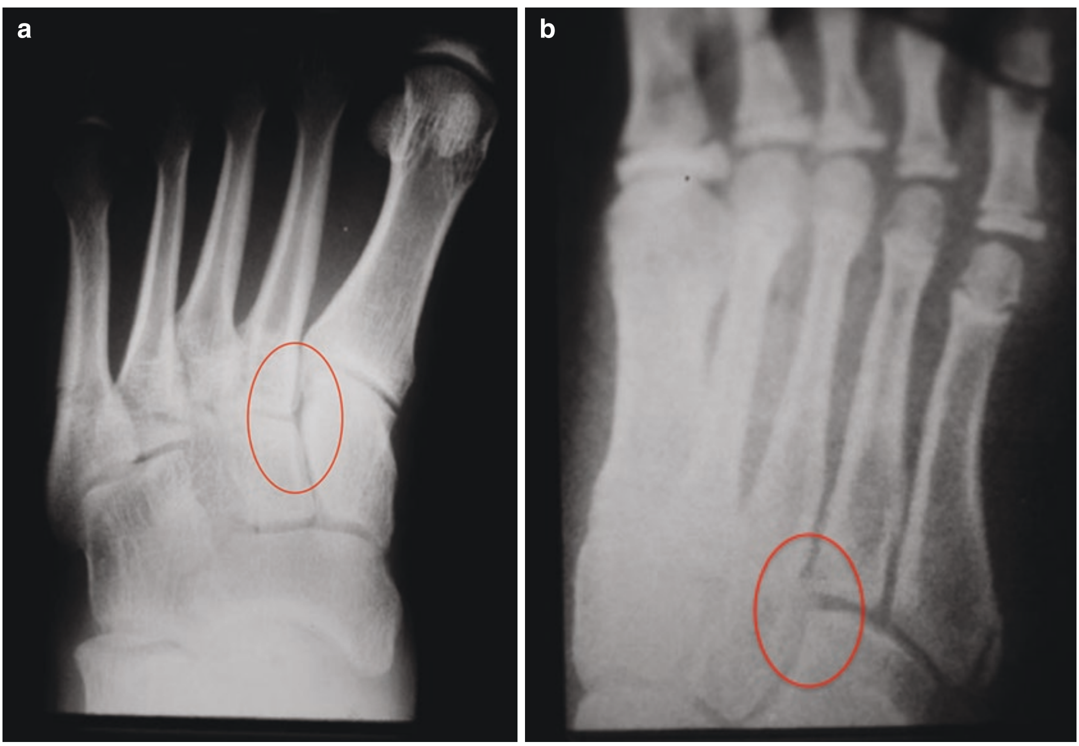

Fig. 8.1 Normal radiographic findings of the Lisfranc joint. (**a**) **AP**: Alignment of the medial border of the second MT with the medial border of the middle cuneiform. (**b**) **Oblique**: Alignment of the medial border of fourth metatarsal with the medial border of the cuboid bone

is a high index of suspicion for a Lisfranc injury in the setting of inconclusive plain radiographs or in patients who are unable to perform weight-bearing imaging [5, 12, 13]. CT scan may identify occult fractures, assess intra-articular extension of fractures, and detect subtle subluxation of pertinent joints [13]. MRI may be useful in the evaluation of the extent of soft tissue damage associated with purely ligamentous Lisfranc injuries [12]. Advanced imaging may also provide additional benefit in preoperative planning for severely comminuted osseous injuries [8].

Fig. 8.2 The "fleck" sign

8.4 Lisfranc Injury Classification

There are a variety of classification systems for Lisfranc injuries, although none have demonstrated significant efficacy in determining optimal management or predicting outcomes.

In 1909, Quenu and Kuss were the first to use standardized terminology to describe Lisfranc injuries using a system based on mechanism of injury and the direction of the metatarsal dislocation [3, 12]. The terminology was later modified in 1982 by Hardcastle et al. who observed that the level of joint displacement seemed to have a greater influence on prognosis than mechanism of injury [3, 5, 11, 14]. In 1986, Myerson et al. used the scaffold of the earlier classifications to develop a system based on the columnar structure of the foot. The medial column consists of the first TMT and medial naviculo-cuneiform joints. The middle column comprises the articulations between the second and third TMT joints as well as the articulations between the middle and lateral cuneiforms and the navicular. The lateral column encompasses the articulations between the fourth and fifth metatarsals and the cuboid bone [3, 10, 14]. The Myerson Classification emphasizes the strong prognostic implications of column-specific midfoot motion and is currently the most commonly used system [3]. However, the current classification systems often only describe the high-energy or traumatic subset of Lisfranc injuries [7]. Thus, more recently in 2002, Nunley and Vertullo developed a classification system to specifically describe the more subtle, low-energy Lisfranc injuries occurring in athletes [3, 7, 8, 15] (Table 8.1).

Table 8.1 Lisfranc injury classifications

Quenu and Kuss (1909)		Hardcastle (1982)		Myerson (1986)		Nunley and Vertullo[a] (2002)	
Homolateral	All MTs displaced in the same direction	A	Complete displacement of all MTs	A	Total incongruity	I	Negative radiographs Increased uptake on bone scan
Isolated	Displacement of only one or two MTs	B	Displacement of one or more MTs	B	Partial incongruity B1: Medial B2: Lateral	II	1–5 mm diastasis between first and second MTs No loss of midfoot arch height
Divergent	MTs displaced in different directions	C	Divergent	C	Divergent C1: Partial C2: Total	III	>5 mm diastasis Loss of midfoot arch height

[a]Classification criteria are based on comparison with the uninjured contralateral foot

While classification systems effectively standardize terminology and provide a method to communicate injury patterns, many surgeons use clinical signs of instability in lieu of structured classifications to guide their medical decision-making. Clinically, Lisfranc injuries may be classified based on stability: unstable injuries present with mild to marked displacement (>2 mm) and typically require surgery while stable injuries with no or minimal displacement (>2 mm) are variably amenable to non-operative management [8].

8.5 Non-operative Treatment

All Lisfranc injuries in the acute setting should be managed following the standard PRICE-M approach: protection with immobilization, rest with weight-bearing restrictions, ice, compression, elevation, and medications for analgesia.

Following confirmation with either stress radiographs, CT scan, or MRI, stable Lisfranc injuries, whether osseous or ligamentous, can be managed non-operatively for the duration of the treatment protocol [8–10]. Other indications and contraindications for non-operative treatment of Lisfranc injuries are described in (Table 8.2). If there is mild displacement, a closed reduction should be achieved using axial traction and direct manipulation of the metatarsal bases. Percutaneous Kirschner wire (K-wire) fixation may be performed to provide stability to the reduction of simple Lisfranc injuries [5]. When used, K-wires should be directed obliquely across the metatarsal base and into the adjacent tarsal bone. Due to the oblique placement, loss of correction and migration of the metatarsal heads may be better avoided [16].

The non-operative treatment timeline should be individualized for each patient (Table 8.3). Cast immobilization is indicated once there is significant reduction in soft tissue swelling [15]. Patients should be evaluated every 2 weeks with weight-bearing plain radiographs to assess

Table 8.2 Indications and contraindications of management for Lisfranc injury

	Indications	Contraindications

Non-operative management	Stable ligamentous injury
	  No static or dynamic displacement
	Stable osseous injury
	  None to minimal displacement
	Latent instability in nonathletes
	Pes cavus deformity
		Unstable Lisfranc injuries
		  TMT joint misalignment
		  First and second metatarsal diastasis >2 mm
		Latent instability in athletes

Operative management	Emergent injuries[a]
	  Open fracture-dislocation
	  Vascular compromise
	  Acute neuropathy
	  Compartment syndrome
	Unstable ligamentous injury[d]
	Unstable osseous injury
	  Irreducible fracture-dislocation[a]
	  Static malalignment
	  Latent malalignment
	  Intercuneiform displacement >2 mm
	  Displacement between medial cuneiform and second MT >2 mm
	  Latent instability in athletes
	Comminuted fractures[b]
	Athletes
	Pes planus deformity[b]
		Poor surgical candidates
		  Poor wound healing
		  Significant soft tissue injury
		  Vascular insufficiency
		  Medical comorbidities
		  Socioeconomic factors
		  Psychiatric illness
		  Nonambulatory patients

[a]Absolute indication
[b]Relative indication

Table 8.3 Lisfranc injury treatment timeline

Time	Non-operative management[a]	Operative management
Acute injury	PRICE-M protocol[b] Non-weight-bearing Immobilization CAM boot Short-leg cast After reduction of edema	PRICE-M protocol Non-weight-bearing Immobilization CAM boot Short-leg cast Delay surgery for 1–2 weeks after reduction of edema[c]
0–2 weeks	Weight-bearing radiographs If stable Non-weight-bearing Immobilization Short-leg cast If unstable Refer for orthopedic evaluation	Operative intervention performed Immediate postoperative period Non-weight-bearing Plaster splint
2–6 weeks	Weight-bearing radiographs Non-weight-bearing Immobilization Short-leg cast	Removal of sutures Non-weight-bearing Immobilization Short-leg cast CAM boot
6–8 weeks	Weight-bearing radiographs Non-weight or heel-weight-bearing Immobilization Short-leg cast CAM boot	Heel-weight-bearing[d] Immobilization Short-leg cast CAM boot
8–10 weeks		Removal of K-wires in the lateral column [1] Partial weight-bearing[d] Immobilization Short-leg cast CAM boot
10–12 weeks	Weight-bearing radiographs Partial weight-bearing Stiff-sole shoe Semi-rigid arch support orthotic	Weight-bearing radiographs Progressive weight-bearing as tolerated CAM boot Semi-rigid arch support orthotic
12–16 weeks	Weight-bearing radiographs Full weight-bearing Stiff-sole shoe Semi-rigid arch support orthotic Gradual return to sport	Weight-bearing radiographs Athletes <200 lb Full weight-bearing Stiff-sole shoe Semi-rigid arch support orthotic Athletes >200 lb Progressive weight-bearing as tolerated CAM Boot Semi-rigid arch support orthotic
24 weeks	Full return to sport Semi-rigid arch support orthotic	Athletes <200 lb Full return to sport Semi-rigid arch support orthotic Athletes >200 lb Full weight-bearing Stiff-sole shoe Semi-rigid arch support orthotic

[a]Return/persistence of pain or tenderness to palpation should immediately prompt phase regression and secondary evaluation with advanced imaging.
[b]PRICE-M stands for protection (immobilization), rest (weight-bearing restriction), ice, elevation, medication (analgesia)
[c]Non-emergent Lisfranc injuries
[d]Dependent upon patient weight and fixation construct

alignment and stability of the Lisfranc joint. At 6–8 weeks post-injury, patients may be transitioned into a low profile Controlled Ankle Movement (CAM) boot or short-leg cast. If used, K-wires may also be removed at this time. However, the patient will continue non-weight-bearing or heel-weight-bearing restrictions until week 8 or 10. After 10 or 12 weeks, patients may be weaned from the CAM boot or short-leg cast into a stiff-sole shoe with well-molded arch support. Over the course of 2 week, patients will transition to partial weight-bearing [8]. Patients may continue to increase weight-bearing intensity every 2 weeks. Full weight-bearing is not recommended prior to 12 weeks post-injury. Physical therapy may be prescribed to assist with strengthening and gait training [3]. Return of pain or tenderness to palpation at any time during treatment should prompt phase regression and secondary evaluation with imaging [12]. Recovery from a Lisfranc injury may take up to 4 months. Life-long use of a semi-rigid arch support is often recommended [3].

8.6 Non-operative Complications

Complications of non-operative management are attributed to difficulty in obtaining adequate reduction and relative instability of non-operative methods in achieving immobilization of the TMT joint. Closed reduction is often obstructed by bony fragments and soft tissue between the fractured or dislocated structures [16]. Casting provides poor immobilization of the disrupted Lisfranc joint when the integrity of the capsular and ligamentous structures is compromised [1]. Due to failure to maintain reduction and subsequent irritation due to increased motion at the affected joint, non-operative management has been associated with symptomatic degeneration and reflex sympathetic dystrophy syndrome. K-wire fixation has been associated with loss of reduction due to proximal migration of the metatarsals as well as osteolysis and infection along the pin tract [5, 16].

8.7 Non-operative Outcomes

Outcomes following non-operative management of Lisfranc injuries vary based on the severity of injury. Injuries involving a mild degree of TMT displacement tend to have fair outcomes. However, this may not be the case in athletes. Curtis et al. report treatment failure and inferior results following non-operative management in athletes with minimal Lisfranc instability [9]. Closed reduction and casting is reliably unsuccessful in the majority of moderate to severe cases [1, 4, 11, 17]. Furthermore, due to articular damage sustained at the time of injury, many patients develop painful, symptomatic midfoot arthritis and may require fusion of the TMT joint [4, 13].

Although the most invasive nonsurgical option, closed reduction and percutaneous pinning with K-wire has also been conceded as ineffective for unstable Lisfranc injuries due to the high rate of treatment failure [18, 19]. K-wire fixation is recognized as inferior in achieving rigid reconstruction of the Lisfranc joint when compared to cortical screw fixation [2].

8.8 Operative Treatment

Absolute indications for operative management of a TMT joint complex injury include open injuries, acute vascular compromise, neurologic damage, compartment syndrome, and unstable fracture-dislocations [8]. Other indications and contraindications for surgical management of Lisfranc injuries are described in Table 8.2.

Acute, unstable Lisfranc injuries with minimal displacement may be treated electively with surgery in the outpatient setting [8]. Surgery is often delayed for at least 2 weeks to allow for resolution of the associated edema and healing of the damaged soft tissue envelope [3, 10, 19]. Acute, unstable Lisfranc injuries with moderate to severe displacement should be treated surgically as soon as clinically possible. Immediate surgical intervention with external fixation or ORIF is particularly warranted if the acute injury is open or accompanied by neurovascular compromise or compartment syndrome [19]. Chronic unstable or severely comminuted Lisfranc injuries may require primary TMT arthrodesis.

The primary goal of operative management is to restore stability and biomechanical function to the midfoot. As such, maintenance of the anatomic relationships between the bony and soft tissue structures that stabilize the TMT joint complex should be prioritized intraoperatively in order to promote optimal postoperative outcomes.

8.8.1 Preoperative Planning

The patient is positioned supine on a flat Jackson table with a soft bump placed underneath the ipsilateral hip. The bump provides internal rotation to the lower extremity, which allows the foot to remain in optimal, neutral alignment throughout the procedure. All bony prominences are well padded and the contralateral limb is secured to the table. The entire length of the ipsilateral limb should be draped out to allow manipulation of the lower extremity during surgery. A tourniquet for the lower extremity is often utilized during the operation. A tourniquet cuff may be placed on the thigh or calf and inflated or deflated intraoperatively as necessary. The preference at our institution is to place a sterile tourniquet on the ankle using a 4-inch non-latex elastic bandage. The foot may be placed on a sterile radiolucent triangle or a bump to allow for further manipulation intraoperatively. Our preference is to use a sterile bump under the ipsilateral ankle.

General anesthesia or regional anesthesia using a spinal, popliteal fossa, or ankle block may be employed. The authors prefer general anesthesia in conjunction with an ankle block. A local anesthetic (1% lidocaine with 0.25% Marcaine) may be injected into the surgical incisions either preoperatively or postoperatively to provide additional analgesia.

Fluoroscopy is used to identify Lisfranc joint instability, confirm reduction of the TMT joint fracture-dislocation, guide hardware trajectory, and assess the adequacy of anatomic fixation.

Various types and combinations of hardware have been employed for fixation of unstable Lisfranc injuries (Table 8.4). The authors prefer to use K-wires, standard AO screws, and dorsal

Table 8.4 Hardware for operative fixation of Lisfranc injuries

Hardware	Indications	Advantages	Disadvantages
Kirchner (K) wires	Fourth TMT joint Fifth TMT joint	Preserves natural motion of the lateral column	High rates failure when used alone
Standard AO screws	Lisfranc joint Intercuneiform Medial column Middle column	Strong Rigid	Iatrogenic cartilage damage Hardware failure Removal of hardware
Bio-absorbable polylactide screws	Lisfranc joint Intercuneiform Medial column Middle column	Strong Rigid No removal of hardware	Iatrogenic cartilage damage Hardware failure
Extra-articular dorsal plate	ORIF Intra-articular cartilage Multiple unstable TMT joints Adjunct to screw fixation Primary arthrodesis Severely comminuted fractures Significantly damaged intra-articular cartilage	Strong Rigid Preserves cartilage	Plantar gapping Hardware irritation Longer operating time Non-union Mal-union
External fixation	Open injuries Significant edema	Strong Rigid Temporary stabilization	Infection Delayed treatment

Table 8.5 Surgical techniques for Lisfranc injuries

Method	Hardware	Indications	Contraindications
Closed reduction, percutaneous fixation	K-wire	Stable closed injuries Low energy trauma	Unstable injuries Open injuries
Closed reduction, external fixation	External fixator	Stable closed injuries High energy trauma Significant edema	Unstable injuries Open injuries
Open reduction, external fixation	External fixator	Open injuries High energy trauma Compartment syndrome	Stable injuries
Open reduction, internal fixation	K-wires Standard AO screws Extra-articular dorsal plate Bio-absorbable polylactide screws Combination	Unstable injuries Moderate to severe displacement (>2 mm) Moderate to severe angulation (>15°) Athletes Low energy trauma Failed closed reduction and percutaneous fixation	Stable injuries Reducible with splint Significant edema
Primary arthrodesis	K-wires Extra-articular dorsal plate Standard AO screws Combination	Medial column injuries >50% articular cartilage damage Severely comminuted fractures High energy trauma Unstable, purely ligamentous Failed ORIF	Lateral column injuries

extra-articular plates. However, the type and combination of hardware used varies based on the individual injury pattern as well as patient-specific demographic factors.

8.8.2 Operative Techniques

ORIF and primary arthrodesis are the most widely used techniques of operative management for Lisfranc injuries [17]. ORIF and primary arthrodesis reliably return stability to the Lisfranc joint; however, it is debated which surgical technique optimally restores anatomic function to the midfoot [2]. The indications and contraindications of ORIF versus arthrodesis are detailed in Table 8.5.

Primary ORIF is the currently accepted technique for the management of displaced, unstable Lisfranc injuries and is often indicated for treatment of athletes with low-energy injuries, regardless of severity [1, 20]. TMT arthrodesis has been traditionally viewed as a salvage procedure following failure of ORIF [18, 20]. Yet, for various reasons, there has been an increasing trend in arthrodesis as the primary method of fixation [1].

Arthrodesis may be categorized as either complete or partial. Complete arthrodesis consists of fusion across all TMT joints of the foot [18]. However, some argue that loss of motion due to fusion across the medial, middle, and lateral columns of the midfoot would result in a biomechanical deficit [1]. An in vitro study of midfoot biomechanics demonstrated that the three columns of the midfoot vary with respect to inherent motion at each articulation. On average, the lateral column demonstrates approximately 11.1° of motion during supination-pronation while the medial and middle columns only demonstrate 1.5° and 2.6°, respectively [21]. As such, partial arthrodesis is a hybrid fixation-fusion method that attempts to address the column-specific biomechanical differences of the midfoot [2, 18]. Partial arthrodesis may be defined as fusion of the medial and middle columns while the lateral column is either provisionally fixed or left free [18].

8.8.2.1 Open Reduction and Internal Fixation

Surgical Approach

The choice of incision for Lisfranc ORIF is guided by the injury pattern and required exposure (Table 8.6). The authors prefer a dual-incision approach, as it allows access to the

Table 8.6 Surgical approaches to Lisfranc injuries

Incision	Landmark	Approach	Exposure	Dangers
Dorsomedial[a]	Second MT First MT interval	Medial to EHL	1st TMT	Dorsal medial cutaneous nerve (branch of superficial peroneal nerve)
		Between EHL and EHB	First TMT Second TMT Lisfranc ligament	
		Between EHB and second EDL tendon Superficial to dorsalis pedis artery and DPN	Second TMT joint Third TMT joint Lisfranc ligament	Dorsalis pedis artery Deep peroneal nerve
Dorsolateral	Fourth MT Third MT interval	Between EDL and EDB	Third TMT joint Fourth TMT joint Fifth TMT joint	Superficial peroneal nerve branches
Medial	Medial border of first TMT joint	Tibialis anterior tendon insertion	First TMT joint NCJ joint Lisfranc screw Intercuneiform screw Medial plating of first TMT	Dorsal medial cutaneous nerve (branch of superficial peroneal nerve) Tibialis anterior tendon

NCJ Naviculo-cuneiform joint, *DPN* Deep peroneal nerve
[a]Can be extended proximally to access the naviculo-cuneiform joint

medial, middle, and lateral columns of the foot [14, 18].

In the dorsomedial approach to the midfoot, a 15-blade is used to make a 4–5 cm longitudinal incision between the first and second TMT joints on the dorsomedial aspect of the foot [1, 19]. Skin hooks or sens are used to apply gentle traction on the epidermis during dissection. Great care should be taken at the distal most aspect of the incision in order to preserve the integrity of the medial branch of the dorsal medial cutaneous nerve. Following skin exposure, the inferior extensor retinaculum is incised. The exposure continues in the plane between the extensor hallucis longus (EHL) and extensor hallucis brevis (EHB). The EHL tendon sheath is incised dorsally, while the EHL tendon is retracted laterally, and the exposed floor of the EHL tendon sheath is incised. A medial full-thickness flap is created by extending this incision to the medial margin of the first TMT joint. A lateral full-thickness flap is created in a subperiosteal dissection toward the lateral margin of the second TMT joint. The lateral full-thickness flap may be used to protect the adjacent neurovascular bundle throughout the procedure.

A dorsolateral incision can be made to provide access to the third, fourth, and fifth TMT joints, as necessary [1]. For Lisfranc injuries resulting in lateral column instability, our authors use a dorsolateral incision that is parallel over the fourth metatarsal. During incision and dissection, it is important to maintain the integrity of a wide skin bridge between the dorsomedial and dorsolateral incisions in order to avoid necrosis of interarching tissue [18]. After blunt dissection, incision of the inferior extensor retinaculum reveals the underlying extensor digitorum communis (EDC) tendon and the medial margin of the extensor digitorum brevis (EDB) muscle. The EDC and EDB tendons are retracted laterally to expose the third TMT joint capsule. Full-thickness subperiosteal flaps are developed in a similar fashion as the dorsomedial incision, with medial extension toward the lateral aspect of the second TMT joint and lateral extension toward the medial aspect of the fourth TMT joint.

Lastly, a medial incision can be made along the medial utility line to assist with reduction and screw placement across the Lisfranc joint. If indicated, fixation of the intercuneiform joints, the first TMT joint, and the naviculo-cuneiform joint can also be performed through this incision. Using a 15-blade, a 3-cm longitudinal incision is made on the medial border of the first MT base. Dissection is performed along the fiber lines of the tibialis anterior tendon down to the level of the insertion.

Intraoperative Assessment

Once appropriate exposure has been obtained, the fracture-dislocation is debrided of hematoma and irrigated to allow for further assessment of articular damage and to ensure an anatomic reduction. If more than 50% of the medial and middle column joints show evidence of chondral damage, primary midfoot arthrodesis may be used instead of ORIF. There is significant debate regarding primary arthrodesis of the lateral column given the functional advantages of its inherent mobility.

Reduction

Depending on the specific injury pattern of the TMT joint complex, several reduction techniques may be employed. The first MT joint is generally reduced with a supination-external rotation maneuver relative to the proximal bones of the foot. Distinct crests on the dorsal aspects of the first MT and the medial cuneiform should be aligned as closely as possible. Alignment of these dorsal landmarks can guide accurate reduction of the joint.

A K-wire is passed along the intended path of the trans-articular screw or extra-articular plate, across the first MT and the medial cuneiform or across the second MT and the medial cuneiform, to provide provisional fixation. Temporary reduction was confirmed via intraoperative fluoroscopy [1].

Fixation

Once anatomic reduction has been achieved, a variety of options exist for definitive fixation of Lisfranc injuries. In athletes and patients participating in high impact activities, our authors preference is to use either a traditional technique with trans-articular screws or a joint-sparing approach with dorsal extra-articular plates.

Final fixation is performed in a medial to lateral orientation [1, 2, 19]. Trans-articular screws or a dorsal extra-articular plate may be used for definitive stabilization of the first TMT joint [1, 9, 19]. The first trans-articular screw is placed retrograde, starting at the dorsal crest of the first MT metadiaphysis and aimed plantarly toward the medial naviculo-cuneiform joint. The retrograde screw should be countersunk to avoid violation of the cortex and hardware prominence. A second trans-articular screw is then placed in an antegrade manner. Starting at the dorsal edge of the medial cuneiform along the Chopart joint, the antegrade screw is aimed toward the plantar aspect of the first metatarsal metadiaphysis. If an extra-articular plate is used, it is positioned and fixed in the same manner as the trans-articular screws [1].

Attention is then turned to fixation of the Lisfranc joint. A pointed reduction clamp is used to span the joint, with one tine placed on the medial aspect of the medial cuneiform and the other tine placed on the lateral border of the second MT [1]. Special care should be taken to ensure that there is no dorsal or plantar malreduction. It has been observed that plantar displacement of greater than 2 mm may lead to transfer metatarsalgia. Next, anatomic reduction is confirmed with fluoroscopy. A K-wire is passed along the anticipated path of the fixation, beginning at the medial cortical shelf of the medial cuneiform and angling through the proximal metaphysis of second MT. A common error is to aim too plantarly when performing this step. The second MT serves as the "keystone" in the "roman arch" structure of the midfoot; as such, the K-wire should be aimed slightly more dorsally [2]. A trans-articular screw or an extra-articular plate is placed along the trajectory of the provisional fixation.

The second TMT is provisionally reduced and stabilized with a K-wire. Definitive fixation of the second TMT joint is achieved using a trans-articular screw or an extra-articular plate [19]. If necessary, the third TMT is secured in a similar fashion to that of the second TMT.

If the intercuneiform joints are involved in the injury complex, these are also reduced and fixed to ensure complete stabilization of the Lisfranc joint. A trans-articular screw is passed through the cuneiforms and is oriented parallel to the Chopart joint [1, 9]. As the intermetatarsal ligaments are often intact between the third, fourth, and fifth metatarsals, reduction may be obtained indirectly, which allows for percutaneous fixation of these joints [19]. At the conclusion of the procedure, final fluoroscopic images are obtained. Radiographs should demonstrate anatomic reduction of the articular surfaces and appropriate placement of the hardware (Figs. 8.3 and 8.4).

Wound Closure

Wounds are copiously irrigated and suction is used to achieve further visualization of the operative field. The dorsomedial incision is closed first. The floor of the EHL tendon sheath and the associated subperiosteal flaps are repaired with deep absorbable suture, 2-0 or 3-0 vicryl. Through the dorsolateral incision, the subperiosteal flaps and the inferior extensor retinaculum are repaired using the same deep absorbable suture, 2-0 or 3-0 vicryl. A layered superficial closure of both incisions is performed next. The subcutaneous tissue is closed using 2-0 or 3-0 absorbable vicryl suture. The skin is closed superficially with 3-0 monofilament suture, monocryl, via a vertical mattress or simple interrupted stitch. If an intercuneiform screw was placed, a simple superficial closure of the medial incision with 3-0 monocryl or 3-0 nylon may be adequate.

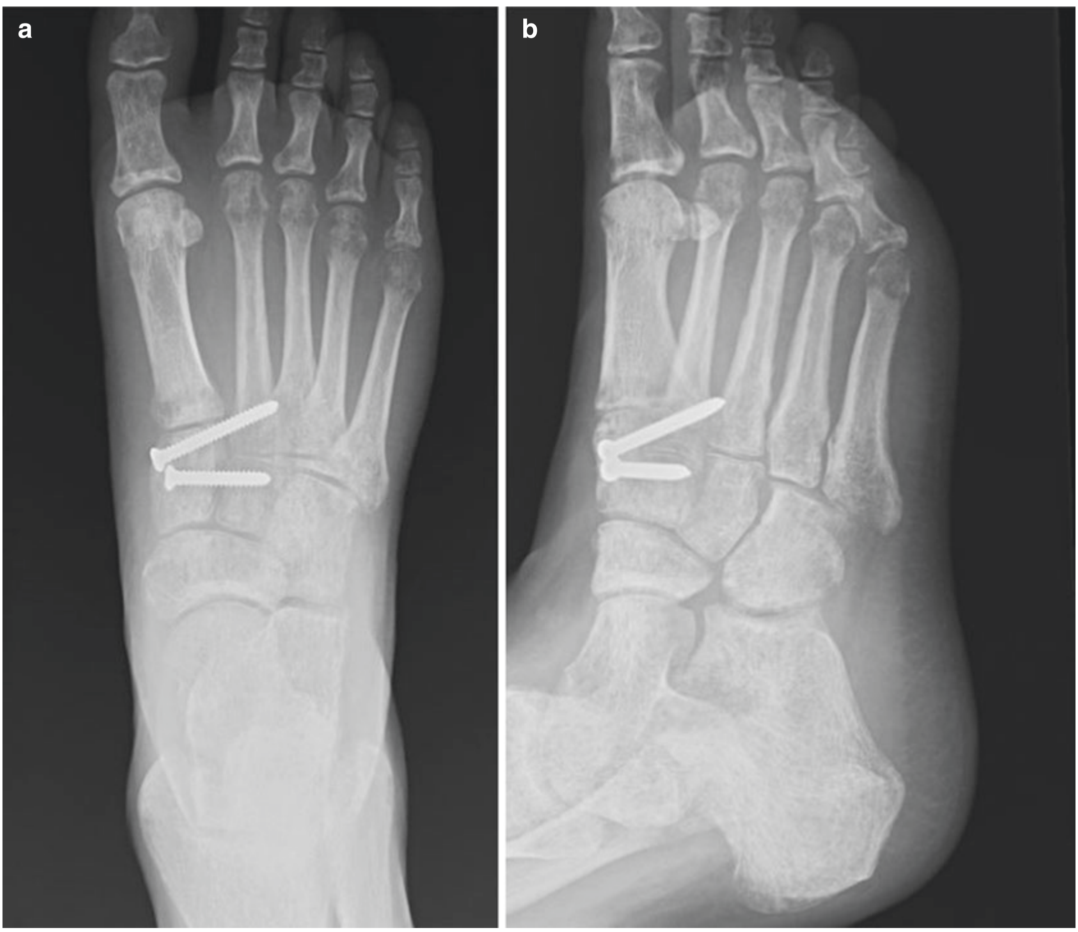

Fig. 8.3 AP (**a**) and oblique (**b**) plain films following open reduction and internal fixation of the Lisfranc joint using trans-articular screws

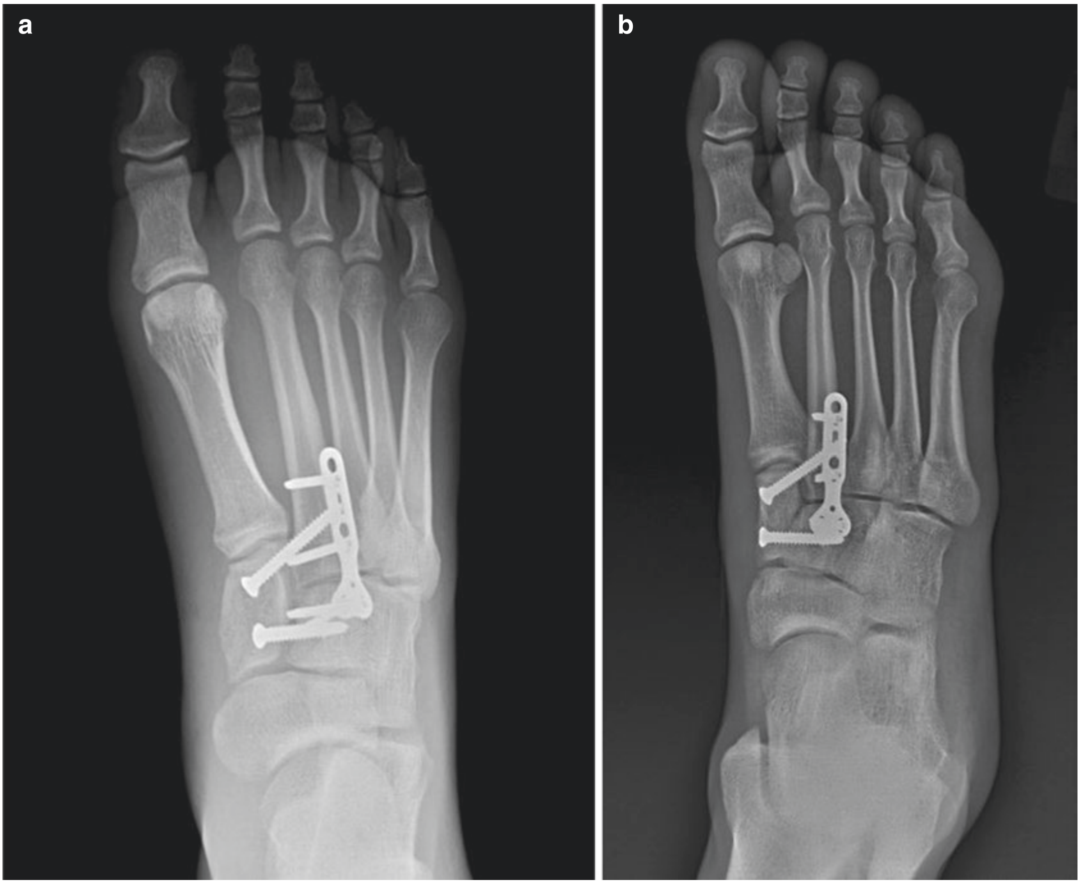

Fig. 8.4 AP (**a**) and oblique (**b**) plain films following open reduction and internal fixation of the Lisfranc joint using a combined technique with trans-articular screws and a dorsal extra-articular plate

8.8.2.2 Primary Arthrodesis

Surgical Approach

The surgical approach for primary arthrodesis is similarly guided by the injury pattern and required exposure. A dual-incision approach is also commonly used for primary arthrodesis in order to access the medial, middle, and lateral columns of the foot.

The dorsomedial, dorsolateral, and medial aspects of the midfoot are incised using the same techniques as described above for ORIF [1].

Intraoperative Assessment

Once appropriate exposure has been obtained, the fracture-dislocation is debrided and irrigated to allow for further assessment of articular damage. Use of a small laminate spreader may allow for better visualization of the involved joint. If more than 50% of the articular surface demonstrates evidence of chondral damage, primary midfoot arthrodesis is indicated. Articular cartilage is removed from the affected joints via controlled movements with a rongeur, osteotome, or curved curette [1]. Special care must be taken to ensure that the subchondral plate is not violated. The exposed subchondral bone can be further perforated in a controlled punctate fashion to allow for cancellous bleeding, which is thought to promote a higher likelihood of fusion. Bone graft from the calcaneus may also be used to promote successful fusion [6, 18].

Reduction

Depending on the injury pattern and number of joints involved, several reduction techniques may be used. The same reductions techniques as those for ORIF may be used during primary arthrodesis.

Alignment should be confirmed using fluoroscopy [6]. A K-wire should be passed along the intended path of the screw to provide provisional fixation.

Fixation

Once anatomic reduction has been achieved, a variety of options exist for definitive fixation of Lisfranc injuries. Fixation is commonly achieved using a solid screw construct across multiple midfoot joints. However, dorsal extra-articular plates may also be used for fusion. Stabilization of the medial column is the recommended first step in fixation as it provides a foundation for subsequent fixation of the lesser metatarsals. Fixation of the medial column is traditionally achieved via placement of a trans-articular screw from the medial cuneiform to the first metatarsal via lag technique or via a dorsal extra-articular plate positioned in the same manner.

Attention is then turned to fixation of the second metatarsal. A pointed reduction clamp is used to ensure anatomic reduction of the second metatarsal into the keystone position. As in ORIF, special care should be taken to ensure that there is no dorsal or plantar malalignment. Anatomic reduction should be confirmed with fluoroscopy. A trans-articular screw or an extra-articular plate is placed from the medial cuneiform to the base of the second metatarsal [1].

If complete arthrodesis is desired, additional trans-articular screws or extra-articular plates may be placed across the remainder of the TMT joint. If partial arthrodesis is desired, percutaneous fixation of the lateral column may be achieved using K-wires. However, depending on the injury pattern, the third-fourth, and fourth-fifth intermetatarsal ligaments may be intact and reduction of the lateral may have been achieved indirectly after fixation of the medial and middle columns. In that case, the lateral column may be left free [18] (Fig. 8.5). Final fluoroscopic images should demonstrate anatomic reduction of the articular surfaces and appropriate placement of all hardware.

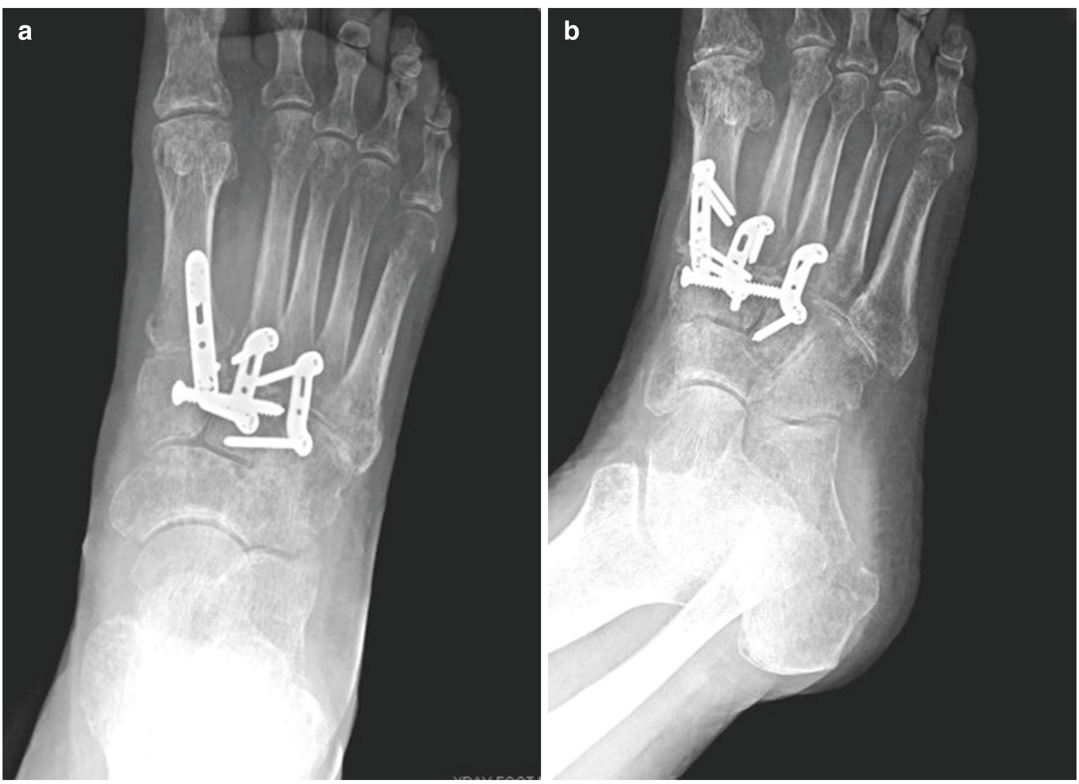

Fig. 8.5 AP (**a**) and oblique (**b**) plain films follwing partial arthrodesis of the Lisfranc joint

Wound Closure

Wounds are copiously irrigated and suctioned for further visualization of the operative field prior to closure. The dorsomedial, dorsolateral, and medial incisions are closed using 2-0 vicryl for the deep closure and 3-0 nylon for superficial closure in the same fashion as detailed above for ORIF.

8.8.3 Postoperative Management

The postoperative timeline is individualized for each patient (Table 8.3). Typically, sterile dressings and a well-padded, bulky posterior short-leg splint are applied in the operating room [19]. Sutures and splint are removed 2 weeks postoperatively. The patient is transitioned into a CAM boot or short-leg cast. If K-wires were used, they are removed around 6 weeks postoperatively [18, 19]. Progressive weight-bearing occurs in a step-wise manner after 6 weeks. Full weight-bearing is not permitted until 10–12 weeks postoperatively, at which point weight-bearing radiographs can be performed. When appropriate, weight-bearing images should confirm maintenance of reduction and appropriate bone healing [1, 3].

Removal of hardware in the postoperative period is highly debated. There is currently no consensus regarding timing, necessity, and role that hardware removal plays in overall patient outcomes [1]. Some surgeons believe that cortical screws involved in medial column fixation should remain implanted indefinitely [19]. Alternatively, other surgeons advocate for routine removal of any and all hardware at 18 weeks to 6 months following the procedure [13, 18–20]. Under the rationale that removal of hardware potentially restores the natural motion of the midfoot, it has been suggested that athletes may benefit from removal of hardware while nonathletes may not [1, 8]. Furthermore, hardware removal among athletes may be influenced by individual weight, such that those >200 pounds should undergo removal of hardware after 24 weeks while those <200 pounds may undergo hardware removal at 12–16 weeks [7, 8].

8.9 Postoperative Complications

The most common complication following operative management of Lisfranc injuries is post-traumatic arthritis, regardless of surgical technique [17]. In a prospective, randomized study, Mulier et al. reported that 94% of patients demonstrated degenerative changes at an average follow-up of 30.1 months. However, surgeons debate whether iatrogenic disruption of the articular surface compounds the pre-existing cartilage damage sustained at the time of injury [3]. Further studies are needed to assess the extent of intraoperative damage during Lisfranc fixation and whether it contributes to the severity of subsequent osteoarthritis [4, 18, 19].

Osteoarthritis is significantly associated with injuries that have not been anatomically reduced at the time of fixation [5, 16, 17]. Adib et al. found that only 35% of patients with anatomic reduction developed osteoarthritis while 80% of those who with nonanatomic reduction developed degenerative changes [17]. However, patients with purely ligamentous Lisfranc injuries demonstrate a higher prevalence of osteoarthritis (40%) compared to combined osseous-ligamentous injuries (18%), despite achieving anatomic reduction [19].

ORIF has also been associated with hardware failure, missed concomitant injuries, deep vein thrombosis, and superficial wound infection as compared to arthrodesis [17]. Persistent pain, midfoot deformity, and symptomatic hardware have also been frequently reported [20, 22]. Primary arthrodesis has also been linked to a greater incidence of pseudoarthrosis, delayed union, and non-union as compared to ORIF [1, 17, 18]. Ly et al. reported specific instances of delayed union and non-union requiring a bone stimulator and revision arthrodesis with bone graft, respectively [20].

8.10 Postoperative Outcomes

Outcomes following Lisfranc injuries are influenced by a variety of factors such as injury pattern, patient-specific demographic factors, diagnostic accuracy, and appropriate management. High-energy traumatic mechanisms and concomitant injuries demonstrate worse outcomes compared to low-energy mechanisms and isolated injuries [13]. Delayed diagnosis and prolonged time to treatment is associated with persistent pain, functional disability, progressive post-traumatic osteoarthritis, and need for salvage arthrodesis [6].

Outcomes following postoperative management also vary based on the surgical technique employed. Following ORIF, fixation of the affected Lisfranc joint in anatomic reduction is an essential factor in determining long-term prognosis [19]. Increased average width between the first and second metatarsal base after ORIF has been associated with worse outcomes among patients with severe Lisfranc injuries [18]. As such, maintenance of accurate reduction is of equal importance, regardless of the severity of injury [2, 11]. Fortunately, anatomic reduction of the Lisfranc joint following rigid fixation appears to be well maintained over the long term. Henning et al. reported that 100% of patients who underwent Lisfranc ORIF maintained anatomic reduction at 2-years follow-up [1]. When anatomic reduction of the midfoot is both achieved and maintained, normal dynamic walking patterns may be restored in the injured foot [22].

Restoration of adequate midfoot function following ORIF has been frequently demonstrated. In a study of patients with radiographically confirmed anatomic reduction, there was a mean American Orthopaedic Foot and Ankle Score (AOFAS) of 78.3 at 42.6 months follow-up [13]. Similarly, Kuo et al. found positive postoperative outcomes, reporting a mean midfoot AOFAS of 77 and a mean Musculoskeletal Function Assessment (MFA) Score of 19 at an average follow-up of 52 months [19]. Patient-reported outcomes following ORIF of Lisfranc injuries also demonstrate positive results. Arntz et al. document that greater than 90% of patients report excellent or satisfactory outcomes following ORIF of the Lisfranc joint using a standard AO technique [3, 17].

While ORIF of Lisfranc injuries generally demonstrates favorable outcomes, the technique often requires second surgery for removal of hardware, whether due to patient dissatisfaction or surgeon preference. Kuo et al. reported that 50% of patients underwent subsequent arthrodesis at an average time of 12 months from initial ORIF due to persistent pain associated with post-traumatic arthritis [19]. Ly et al. reported that 30% of Lisfranc ORIF patients underwent a second surgery for removal of prominent or painful hardware at an average of 6.75 months postoperatively [20]. In a systematic review of the literature, Sheibani-Rad et al. reported an overall higher rate of reoperation among patients after ORIF (75–79%) compared to arthrodesis (17–20%). However, many of the studies included in the systematic review describe scheduled removal of hardware at specified time intervals following the index procedures; and thus, it is possible that the higher rates of operation may be simply due to study design [17]. Further studies are needed in order to provide evidence-based recommendations regarding the specific implications of hardware removal on patient outcomes following ORIF.

Like ORIF, arthrodesis has also demonstrated favorable outcomes. In a study conducted by Henning et al., 94% of patients who underwent primary arthrodesis of the Lisfranc joint maintained anatomic reduction and achieved solid fusion at 2-year follow-up [1]. Due to the high rates of success and nature of the technique, arthrodesis rarely requires additional surgery for hardware removal or revision [1, 20].

Primary arthrodesis appears to have particularly favorable functional outcomes with respect to operative management of purely ligamentous Lisfranc injuries. Ly et al. report significantly higher mean midfoot AOFAS at 2-year follow-up among patients with purely ligamentous Lisfranc injuries who underwent primary arthrodesis compared to those who underwent ORIF, 88 and 68.6, respectively [20]. Purely ligamentous Lisfranc injuries have also shown favorable patient-reported outcomes following primary arthrodesis. Patients with ligamentous injuries reported a return to 92% of their pre-injury level at 2 years following primary arthrodesis. At 2 years, patients also reported an average Visual Analog Pain Scale (VAPS) score of 1.2 compared to an average VAPS score of 4.2 among open reduction patients [20].

Primary arthrodesis may also be considered judiciously as a reasonable option for surgical management of Lisfranc injuries in the young athlete. MacMahon et al. report outcomes regarding return to sports and physical activities at a mean of 5.2 years follow-up following primary partial arthrodesis for Lisfranc injuries in young patients. 47.1% of the athletes' total activities were high impact preoperatively, and 44.8% of the athlete's total activities were high impact postoperatively. 65% of the young athletes were able to return to their preoperative level of participation in physical activity; however, 97% of the athletes reported satisfaction with their return to physical activity postoperatively. In addition, the mean postoperative Foot and Ankle Outcome Scores (FAOS) for pain, activities of daily living (ADL), sports, and quality of life (QOL) subscores were 91.4, 95.9, 85.8, and 75.5, respectively [23].

Both ORIF and arthrodesis are reasonable primary surgical interventions for Lisfranc injuries, and it appears that most patients may experience positive outcomes regardless of the surgical technique employed [17]. Mulier et al. demonstrated no significant difference in pain, foot function, and cosmesis among patients who underwent either ORIF or partial arthrodesis in which only the first through third TMT joints were fused while the fourth and fifth TMT joints were left free [18]. In a more recent study, Henning et al. similarly found no statistical difference in Short Musculoskeletal Function Assessment (SMFA) scores, Short Form Survey 36 (SF-36) scores, and satisfaction rates between primary ORIF and primary arthrodesis patients at an average follow-up of 53 months [1].

Reinhardt et al. also report positive outcomes regarding patient satisfaction, postoperative pain, midfoot function, and return to preinjury activity level following primary partial arthrodesis for both purely ligamentous and combined osseous-ligamentous Lisfranc injuries. 84% of all patients were "somewhat satisfied" or "very satisfied" at latest follow-up postoperatively, and patient satisfaction did not differ between purely ligamentous and combined osseous-ligamentous injury types. The average VAS score across groups was 1.8 at latest follow-up postoperatively, and average pain scores did not differ significantly between the Lisfranc injury types. Also, functional outcomes measures on both the AOFAS midfoot scale and the Short Form-36 (SF-36) mental and physical scales did not demonstrate any statistical difference between the purely ligamentous and combined osseous-ligamentous Lisfranc injury types. The overall average AOFAS midfoot score at final follow-up was 81, and patients reported a return to an average of 85% of their preinjury level of activity [24].

8.11 Conclusion

Injury to the Lisfranc joint is rare and commonly missed or misdiagnosed. These injuries may cause significant damage to the midfoot resulting in disabling morbidity. Thus, timely identification and appropriate treatment of Lisfranc injuries are important. Stable Lisfranc injuries with minimal displacement are amenable to a trial of non-operative management. However, non-operative management in the competitive athlete is recommended with caution, as there is a higher likelihood of treatment failure. Unstable injuries with moderate to severe displacement require prompt surgical management in both the athlete and nonathlete. Although ORIF has been accepted as the standard for operative management, primary arthrodesis has become an increasingly favorable option among surgeons. Arthrodesis appears to have a unique application in that studies cite superior outcomes in purely ligamentous Lisfranc injuries as compared to ORIF. However, both surgical techniques are reasonably controversial in nature. ORIF has been associated with high rates of reoperation due to planned removal of hardware, and primary arthrodesis has been associated with a loss of natural biomechanical function within the midfoot. While anatomic reduction is highly recognized as an essential factor in promoting positive outcomes, there is currently no consensus regarding the ideal operative method for the treatment of Lisfranc injuries.

8.12 Senior Author's Statement

With the above said, the senior author prefers ORIF via extra-articular fixation with planned hardware removal in the athletic population with a goal of restoring stability of the Lisfranc complex while maintaining biomechanical function of the midfoot.

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