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Assessment of the Typology of Lisfranc Injuries of the Foot

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Abstract

Background: Although Lisfranc fractures and dislocations can occur at the second tarso-metatarsal (TMT) joint or combined with other midfoot, Chopart, and ankle joint injuries, they are typically recognized as midfoot injuries. Our hypothesis is that Lisfranc injuries have more complex patterns than have been widely recognized, with other midfoot and hindfoot involvement. None of the previous studies so far have provided a comprehensive picture of the complexity of Lisfranc injuries, and the optimal management of Lisfranc injury is still unclear. This paper is an attempt to obtain a typology of Lisfranc injuries combined with other foot bones and joints involvement, using a combination of initial injury radiographs, preoperative computed tomographic (CT) scans or magnetic resonance images (MRI), and intra-operative image intensifier (II) screening. We also looked the treatments given for each type.

Methods: Between 2013 and 2015, a total of 54 patients (56 feet) were identified, all with Lisfranc injuries, and were treated at our institute. We retrospectively analyzed the patients' pre-operative initial injury, or stress view radiographs, MRI, or CT, or intra-operative II screening, to look at the typology of Lisfranc injuries.

Results: We found different complexities of Lisfranc injuries as follows: Type 1, ligament injury, Type 2, presence of associated metatarsal base fracture or dislocation, and Type 3, Lisfranc injury, combined with either Chopart joint fracture or ankle fracture.

Conclusion: Lisfranc injuries with associated fractures and dislocations appear to be highly variable and complex. We identified certain types of Lisfranc injuries which were not categorized in previous classification systems. There were many Lisfranc fractures or dislocations associated with midfoot, Chopart, and ankle joint injuries. All the cases were treated by operative fixation, except Type Ia. Lisfranc injuries can vary from subtle ligament problems to ones associated with high energy complex fractures. This study will give some insights into the variation in Lisfranc injuries.

Keywords: Midfoot Fracture; Lisfranc Injury; Chopart Joint; Outcome; And Internal Fixation

Introduction

Lisfranc injuries have commonly been recognized as minimal dissociations between the bases of the five metatarsals (MTs) and their articulations with the four distal tarsal bones. Typically, Lisfranc injuries mean a rupture of the Lisfranc ligament, an interosseous ligament located between the medial cuneiform and the second MT.

It is important to fully recognize, classify, and introduce adequate treatment of the different severities of Lisfranc injuries. It is known that as many as 20% of subtle Lisfranc injuries are either missed or misdiagnosed, which can lead to wrong treatment. This may become a permanent source of foot pain and loss of function [1]. The main reason for misdiagnosis is reported to be because

20% to 50% of Lisfranc injuries are negative in initial radiographs [2]. If CT and MRI scans are taken, the misdiagnosis rate should be lower and subtler Lisfranc injuries should be recognized. In addition, Lisfranc injuries are reported to co-exist with other tarsal fractures or dislocations [3]. This study aims to look at the typology of Lisfranc injuries using a combination of initial injury radiographs and CT or/and MRI images, and compared with the widely used Lisfranc classification by Myerson, based on different types of fractures diagnosed by plain radiographs. The purpose of this study is to analyze the variation in fracture/dislocation patterns of the Lisfranc injuries and related other injuries.

Materials and methods

Ethical approval for this study was obtained from research review boards. We retrospectively analyzed images and the operative notes of 54 patients (56 feet) with a. Lisfranc injuries in isolation, b. midfoot injuries, and c. Lisfranc injuries combined with Chopart and ankle injuries. Data was taken from two orthopedic centers, between Jan 2010 and Jan 2015. They were a tertiary level major trauma centre and a level II multi-specialty hospital. All images we included were plain radiographs, prior to operation and post reduction of fracture, intra-operative image intensifier (II) screening, CT scans or MRI scans. These were analyzed for fracture patterns and for evidence of subtle Lisfranc injuries. The initial injury radiographs of AP, lateral, and oblique views were used to analyze the location of the fractures and direction of the dislocation or subluxation.

We observed: 1) dislocation or subluxation of Lisfranc joint in the coronal and/or sagittal plane; 2) evidence of midfoot joint dislocation/fractures in AP, lateral and oblique views; 3) presence of more than 2 mm diastasis between the medial cuneiform and the base of the second MT, compared with contralateral foot; 4) fractures of MTs and tarsal bones; 5) Lisfranc injuries associated with Chopart joint dislocations; 6) Lisfranc injuries associated with ankle fractures. MRI was also used to assess Lisfranc ligament injuries, indicated by the rupture of the ligament signals. CT scans were used to detect a widening between the medial cuneiform and the base of the second MT, and to check for other injuries among tarsal bones, Chopart joints, and ankle joints. The severity of injury, the stability of the midfoot, and intra-operative II screening images were all collected. The treatment, including surgery or non-surgery, fixation methods, and patient operative notes were also analyzed. We subsequently used the following typology to classify Lisfranc injuries:

Type 1: ligament injury. This can be seen as a ligament sprain (partial tear) or complete rupture by MRI or physical examination under anesthesia, showing laxity, and can be subdivided as follows:1a: Lisfranc ligament tear by itself, 1b: Lisfranc ligament tear combined with TMT ligament rupture, and 1c: Lisfranc ligament tear combined with tarsal bone ligament rupture.

Type 2: Lisfranc ligament injury with MT or tarsal bone fracture: 2a: Lisfranc ligament injury combined with second MT base fracture, 2b: Lisfranc ligament injury combined with MT base fracture or dislocation, and 2c: Lisfranc ligament injury combined with tarsal bone fracture or dislocation (such as cuneiform fracture or dislocation)

Type 3: Associated fractures: 3a: Lisfranc ligament injury combined with Chopart joint dislocation or fracture, and 3b: Lisfranc ligament injury combined with ankle fracture

An extensive literature search was performed, using MEDLINE (1996 to present), Pub Med and Cochrane databases, to find journal articles referring to Lisfranc dislocations and fractures. The keywords used were midfoot fractures, Lisfranc injury, Chopart joint, and internal fixation. Search results were limited to humans and articles in the English language. All patients included in this study were followed up postoperatively at least one year later using the American Orthopedic Foot and Ankle Society (AOFAS).

Results

Ofthe 54 patients, 41 were male and 13 females. They were divided in groups by our classification (Table 1).

patient	age	sex	Type I			Type II			Type III	
			a: Lis ligament	b: TMT ligament	c: tarsal ligament	a: 2MT fracture	b: MTs fracture	c: tarsal fracture	a: Chopart	b: ankle fracture
1	37	F	X							
2	16	M	X							
3	21	F	X							
4	46	M		X						
5	32	F		X						
6	43	M		X						
7	34	M		X						
8	30	M		X						

9	29	M		X						
10	37	F		X						
11	30	M		X						
12	45	M			X					
13	43	M			X					
14	48	M			X					
15	52	F				X				
16	54	M	X				X			
17	36	M					X			
18	35	M					X			
19	23	M					X			
20	38	M					X			
21	34	M					X			
22	37	M					X			
23	28	M					X			
24	60	M					X			
25	55	M					X			
26	36	M					X			
27	38	F					X			
28	43	M						X		
29	40	F						X		
30	28	M						X		
31	32	M						X		
32	68	F						X		
33	54	M						X		
34	27	M						X		
35	48	M						X		
36	28	M						X		
37	47	F						X		
38	58	M						X		
39	25	M						X		
40	29	M						X		
41	19	M						X		
42	19	M						X		
43	45	M							X	
44	44	F							X	
45	43	M							X	
46	54	F							X	
47	61	F							X	
48	54	M								X
49	68	M						X		X
50	23	M								X
51	40	M								X

52	25	F								X
53	51	M								X
54	61	M								X

Table 1: data of 54 patients (56 feet)

Average age was 38.7 years (range, 16 to 68). Of these, 52 patients had CT examinations, and 3 patients had MRI examinations, and 3 patients had conservative treatment (casting and non-weight bearing for six weeks); 51 patients (53 feet) underwent surgical repairs; 4 cases were only fixed with trans-articular screws, while other cases were fixed with a combination of trans-articular screws and bridging plates (Table 2).

	Type 1a (3 cases)	Type 1b (8 cases)	Type 1c (3 cases)	Type 2a (1 case)	Type 2b (12 cases)	Type 2c (15 cases)	Type 3a (5 cases)	Type 3b (7 cases)
trans-articular screws		3				1		
bridging plate		5	3	1	12	14	5	7
conservative		3						

Table 2: Treatment details

The choice of surgical approach was made according to the fracture pattern and the preferences of the surgeons.

We found different types of Lisfranc injuries and classified them (Table 3-10). All patients were followed up, one year postoperatively, based on the AOFAS foot ankle score system. The average score in this study was 81.3 points, and the score was evaluated by types. The average score of (Type Ia-Ic) was 90.5 points. The average score of (Type IIa-IIc) was 80.3, among which (Type IIa) was 86.4 points, (Type IIb) 83.4 was points, and (Type IIc) was 76.9 points. The average score of (Type IIIa-IIIb) was 73.0 points, among which the (Type IIIa) was 79.7 points, and the (Type IIIb) was 68.2 points.

Table3 : Type 1a: Lisfranc ligament tear.

Table 4: Type 1b: combined with other TMT ligament tear.

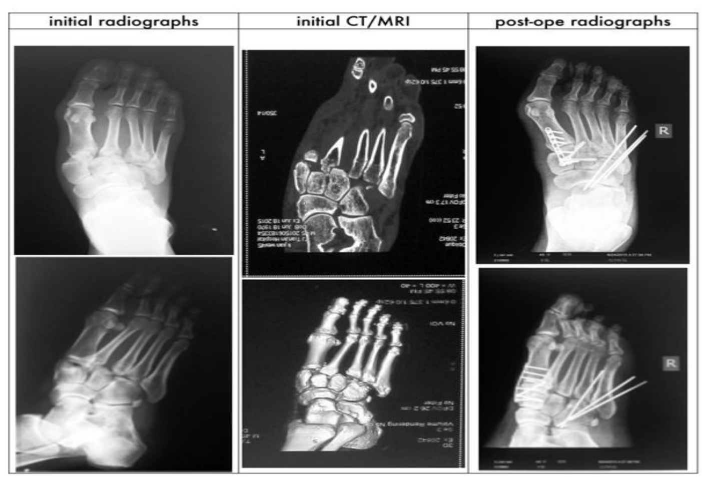

Table 5: Type 1c: combined with tarsal bone ligaments tears.

Table 6: Type IIa: combined with base of the second MT fracture.

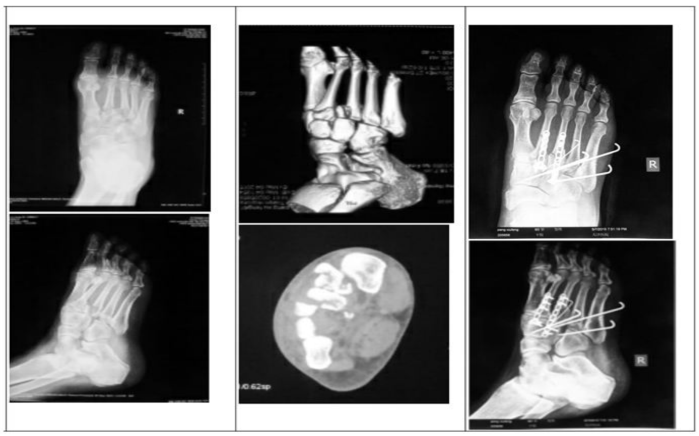

Table 7: Type IIb: combined with other MT fracture/ dislocation.

Table 8: Type IIc: combined with tarsal bone fractures/ dislocation.

Table 9: Type IIIa: Lisfranc injury combined with Chopart joint dislocations / fractures.

Table 10: Type IIIb: Lisfranc injury combined with ankle fracture.

Discussion

The special quality of midfoot anatomy and biomechanics was first noted by Jacques Lisfranc de St. Martin, a field surgeon in Napoleon's army who served on the Russian front [4].This area of the midfoot then became known as the Lisfranc joint, and later the associated ligament was named the Lisfranc ligament. It connects the second metatarsal base and medial cuneiform. It is an oblique ligament. In the coronal plane, the bones of the Lisfranc joints have a Romanesque arch shape, with the apex at the second metatarsal. Although the base of this metatarsal is recessed into cuneiforms, which adds to its overall stability, there is no inter-metatarsal ligament between the 1st and 2nd inter-metatarsals. The midfoot ligaments are composed of plantar, interosseous, and dorsal parts [5].The interosseous and plantar inter-metatarsal ligaments are the strongest stabilizers of this construct, and the dorsal ligaments are the weakest [6].This biomechanical construct means that the midfoot is susceptible to injury from torsion of the forefoot and axial load.

Injuries to the tarso-metatarsal (TMT) complex can be designated as indirect or direct. Indirect injuries can be high energy, such as in motor vehicle accidents or falls from a height, or caused by low-energy forces, such as those incurred during athletic activity [7]. Most commonly, indirect injuries are associated with a longitudinal force applied to the forefoot, which is then subjected to rotation and compression causing Lisfranc ligament rupture [8]. Further excessive plantar flexion and abduction are the most common causes leading to MT dislocations or fractures [9].

Lisfranc joint and associated injuries

A few Lisfranc injury classification systems have been proposed and updated in the past, mostly based on joint incongruity. These past classification systems are effective in standardizing terminology and allowing for some description of the injuries, however, wehaven't got a comprehensive classification for determining the management of injuries and predicting clinical outcome.

In 1909, Quenu and Kuss in their work on TMT injuries, made their prognosis depending on joint incongruity[10]. In 1986, Myerson et al proposed a classification system of Lisfranc injuries as follows: Type A, total incongruity of the TMT joint; Type B1, partial incongruity affecting the first row in relative isolation (partial medial incongruity); Type B2, partial incongruity in which the displacement affects one or more of the lateral four MTs (partial lateral incongruity); and types C1 and C2, divergent patterns, with partial or total displacements [11].

Chiodo and Myerson, following in 2001, described a columnar classification of TMT joint injuries based on the three mechanical columns of the foot [12]. In this system, based on midfoot anatomy and biomechanics, the medial column is composed of the medial cuneiform and the first metatarsal, the middle column is made up of the second and third metatarsals and the intermediate and lateral cuneiforms, respectively, and lastly, the lateral column is composed of the cuboid and the fourth and fifth metatarsals, while the navicular bridges the medial and middle columns [13]. It is true that the articulation between the cuboid and navicular can vary in configuration, from a true synovial joint to fibrous synchondrosis [14]. The lateral articulations between the cuboid and the fourth and fifth metatarsals are significantly more mobile than in the central or medial columns. The lateral column joints have arcs of motion of approximately 20 degree in flexion-extension and rotation. The middle cuneiform-second metatarsal articulation has the least amount of motion in the midfoot (less than four degree in the sagittal plane), likely as a result of its anatomic constraints [15].

We looked at Lisfranc injuries, not by following exactly the widely used joint incongruity classification of Myerson et al, [4] but according to the extent of its injury.Regarding our type 1 (ligament injuries), we noted that there are different degrees of lisfranc ligamentous injury. On MRI images these can be seen as ligament sprains, or complete tears, and the injury patterns are classified as simple Lisfranc ligament tear (1a), TMT ligament rupture combination (1b), or tarsal bone ligament rupture combination (1c).

There is also a report by Nunley and Vertullo who classify athletic Lisfranc ligament injuries into three groups based on clinical findings, weight-bearing radiographs, and bone scan [16]. Their stage I injury involves pain but negative radiographic findings, with only increased uptake in bone scan at the Lisfranc complex. Stage II injuries exhibited diastasis between the first and second MTs of 1 to 5 mm greater than that on the contra-lateral side, without loss of foot arch height. Diastasis of more than 5 mm and the loss of arch height signified stage III injury. Non-surgical treatment of stage I patients and surgical treatment of stage II and III patients led to an excellent result in 93% of cases. In their report, Nunley and Vertullo argued that traditional classification systems lack emphasis on the simple diastasis seen in low-energy athletic injuries. In our typology assessment, we agree with the traditional classification system of Chiodo and Myerson which does not include low-energy injuries.

In our study, three simple Lisfranc ligament injuries, Type1a, out of 14 cases of type I had conservative treatment. The average score of type I is 90.5 points. These were all excellent results except for the one non-surgical case, a partial tear on Lisfranc ligamentous injury, shown by MRI, with a slight antalgic gait due to second TMT joint arthritis. This case alerts to the importance of diagnosis of ligamentous injury as well as whether it is appropriate to have non-surgical management of Lisfranc ligamentous injuries.Our typology analysis results also showed many combinations of Lisfranc injuries such as our Type 2 and 3, with other fractures and dislocations of the midfoot, hindfoot, and ankle joints. The traditional classification systems do not only include low-energy injuries, but also do not include a large range of injury patterns of multiple trauma and high energy injuries.

Although the most common area of midfoot injury is in the Lisfranc joint, Lisfranc injuries are reported to co-exist with tarsal fractures or dislocations [3]. In this report we have showed relatively high numbers of cases of Lisfranc injuries associated with other Type 2c and Type 3b injuries, combined with tarsal bone and ankle fractures and dislocations. Because the outcomes of these associated injuries correlate with the degree of anatomical incongruency of the Lisfranc joints, in our point of view it is important to look at the foot injuries in terms of the typologies of Lisfranc injury [17, 18].

This is also supported by Richter et al's 2001 retrospective review of 155 patients with midfoot injuries. In this study, functional outcomes, as measured by the AOFAS clinical rating scale, were significantly worse for patients with combined Chopart and midfoot injuries, than for those with either injury by itself [19]. These combined injuries, which are often associated with high-energy motor vehicle accidents, can lead to significant arthrosis of the TMT joints through altered joint kinematics and altered loading. However, they are frequently missed in diagnosis, when they are associated with additional trauma [20].Our analysis of typologies of Lisfranc injuries should clarify highly variable midfoot injuries, to minimize future misdiagnosis using our typology.

Management

The midfoot complex has a dynamic mechanical role that allows the load to be effectively transferred to the forefoot during walking. The motion of each midfoot joint is variable and complicated. The Chopart joint is rigid at toe off, but it becomes a flexible structure during heel strike that increases the lever arm of the Achilles complex [21].

If missed, Lisfranc injuries can lead to post-traumatic arthritis, reported in nearly 50% of cases [22]. Fractures and fracture-dislocations of these bones can result in severe functional impairment and arthrosis. Therefore initial surgical intervention is recommended to realign the articulations, which has been found to improve function [23]. Patients with displaced or unstable injuries require surgical treatment with anatomical reduction [24].

Eleftheriou reported that post-traumatic arthritis is more common at the base of the second MT, suggesting that incongruity may be better tolerated at the medial and lateral columns [25]. The lateral column, which has the greatest amount of plane motion, is the least likely to be involved in post-traumatic arthritis. Since the middle and the medial columns are relatively rigid, they are stabilized with screw fixation or dorsal plating. K-wire fixation is used for the more mobile lateral column [26].

Judging by our experience treating advanced adult acquired flat-foot, the structural abnormalities of valgus of the calcaneus, forefoot abduction, and loss of the longitudinal arch lead to midfoot arthritis [27,28]. Attention to the hindfoot and forefoot alignment, as well as restoring midfoot arch during surgery, is the key to restoring post-traumatic foot function. In addition, pathologic conditions of the midfoot (e.g. inflammatory arthropathy with synovitis and joint destruction) are often reported to lead to pain and instability. Loss of midfoot stability may manifest itself as abnormal foot posture with the collapse of the longitudinal arch, causing increased tensile loading on the plantar ligaments, resulting in foot pain [29].

In general, we think all subtypes require surgical management, either internal fixation or primary arthrodesis, except Type 1a which can be treated non-surgically. We think stable and non-displaced injuries like Type 1a can be managed non-surgically with a non-weight-bearing cast for six weeks, following the previous outcomes of this treatment modality, with the majority of patients returning to their pre-injury sporting activities [30]. For complete ligamentous rupture, a longer period of immobilization may be required, lasting three to four months.We have managed surgically all of our cases of Types 1b and 1c.

Nevertheless controversy remains regarding the treatment of patients with extensive articular damage (multiple joint fragments), and also those with complete ligamentous rupture [31]. The current treatment of both these types of injuries is often with open reduction internal fixation (ORIF), although it has been proposed that primary arthrodesis may be more suitable [32]. The cartilage is removed to prepare the joint and the screws are placed under compression [33]. This is often considered as an alternative, as it has been shown that purely ligamentous injuries to the Lisfranc joint do not always heal after ORIF and consequentially there is an increase in joint degeneration [34].Furthermore, up to 94% of patients go on to develop arthritis later on, which requires secondary arthrodesis of the TMT joints [35]. Further analysis is required in order to suggest the best surgical management according to our classification.

In terms of surgical options, bridge plates or trans-articular screws are currently in discussion. The majority of operative treatments of Lisfranc fractures and dislocations currently consist of open reduction and trans-articular screw fixations. In our study, bridge plates have been used more often. This is because we use a joint-spanning technique, which enables fracture dislocations to be stabilized with minimal articular damage. Bridge plating for Lisfranc injuries has showed at least similar functional outcomes, compared with trans-articular fixation [36].

In a cadaver study of 20 specimens comparing dorsal plates and trans-articular screws, it was found that screw placement led to additional damage to the articular surface of 2% to 6%, but they found no difference in displacement distances after loading, thus the conclusion was that both methods prove similar stability [37]. Kuo et al reported that screw fixation leads to superior temporary stability and has potential for early recovery [38].

Radiographic Imaging

Lisfranc injuries are a challenge to diagnosis. Approximately 20% of injuries go unrecognized [39].This is probably due to the difficulty encountered with standard radiographic imaging. Initial imaging of a suspected Lisfranc injury should include routine anterior-posterior (AP), lateral, and oblique views of the foot, with the image taken parallel to the midfoot joints. To aid in the diagnosis of more subtle injuries, a weight-bearing film with both feet on a single X-ray cassette should be obtained. This last view serves as a stress view of the foot.

AP radiographs are used to demonstrate mal-alignment of the first and second TMT joints, although incongruity of the third and fourth joints is better visualized at a 30 degree oblique angle

[40]. For the lateral view, the dorsal and plantar aspects of the MTs should correspond with the cuneiform and cuboid. A tangential line drawn through the medial aspect of the medial cuneiform and navicular should intersect the first MT base [41]. Lateral weight-bearing radiographs can be used to identify flattening of the longitudinal arch as well as dorsal displacement at the second TMT joint. These are often enough to demonstrate more obvious Lisfranc fracture dislocations, but miss a significant number of more subtle injuries [42]. It has been shown that in up to 50% of the patients, non-weight-bearing radiographs were normal and missed the diastasis between the first and the second metatarsals. It has therefore been suggested that weight-bearing radiographs should be used to identify subtle Lisfranc injuries. Since a weight-bearing radiograph can be very painful, some advocate that it should be performed under local anesthesia with an ankle block [43]. The 'fleck sign', a small chip of bone found in the space between the first and second metatarsal bases, indicates avulsion of the Lisfranc ligament [44, 45]. The AP and oblique radiographs should be investigated for this finding.

Radiographic studies can also be done to determine whether an injury is stable or unstable. The AP radiograph should show alignment of the medial border of the second MT and the medial border of the middle cuneiform. The oblique view should show alignment of the medial border of the fourth MT and the medial border of the cuboid. Close examination of these lines for displacement will help the clinician with subtle cases. Diastasis between the first MT-medial cuneiform and second MT of more than 2 mm greater than on the contra-lateral side, or TMT joint subluxation of more than 2 mm greater than on the contra-lateral side, indicates instability and is a reason for surgical intervention [46]. Diastasis between the first and second MT in the injured midfoot is considered normal, provided that it measures less than 2.7 mm [47]. The most common abnormality in Lisfranc injuries is the lateral step-off at the second TMT joint.

Additional investigations may be helpful, including ones related to bone scans, MRI, and CT. These images may demonstrate comminution and intra-articular extension or interposed soft tissues, not appreciable from the initial radiographic assessments [48]. Bone scans are typically reserved for patients with midfoot injuries but negative radiographic findings [49]. When plain radiographs and the physical examination are insufficient, MRI can be used to provide excellent depiction of the soft tissues [50,51]. Additionally, for high-level athletes, MRI may provide information for the treating physician to make a determination on return-to-play status. In a recent study evaluating the predictive value of MRI for midfoot instability, Raikin et alfound that MRI images, demonstrating a rupture or grade II sprain of the plantar ligament between the first cuneiform and the bases of the second and third MTs, can be highly predictive of midfoot instability [52]. These patients should be treated with surgical stabilization. CT is recommended in patients presenting high-energy injuries in which improved detection and delineation of fractures is required. However, subtle displacement may not be demonstrated because this is a non-weight-bearing examination.

Subtle Lisfranc injuries are the most difficult to diagnose and manage. These injuries often have inter-cuneiform extension, with the injury exiting through the medial naviculo-cuneiform facet. Most surgeons believe that pure ligamentous injuries take far longer to heal than do their bony counterparts [53]. A novel approach to these difficult cases may improve outcomes with a more rapid return to sports. It has been suggested that MR imaging has a sensitivity and predictive value of 94% with regard to Lisfranc joint instability, and can therefore be extremely useful for diagnosing subtle Lisfranc injuries [54].

Summary

Lisfranc injuries with associated fractures and dislocations appear to be highly variable and complex. We identified certain types of Lisfranc injuries which we put into different categories. There were many Lisfranc fractures or dislocations as part of other midfoot, Chopart, and ankle joint problems. Lisfranc injuries can be complex, and we should be aware of the variation of midfoot types. Based on our data, correct decision making is essential prior to embarking on operative fixation, and further analysis of the patterns of injuries is required in order to choose the method of surgical management, according to our typology of Lisfranc injuries.

Conflict of Interest: The authors declare no conflicts of interest associated with this manuscript.

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