Lisfranc injuries: incidence, mechanisms of injury and predictors of instability.

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ABASTRACT

Background:
In Lisfranc injuries the stability of the tarsometatarsal joints guides the treatment of the injury. Determining the stability, especially in the subtle Lisfranc injuries, can be challenging. The purpose of this study was to identify incidence, mechanisms of injury and predictors for instability in Lisfranc injuries.

Methods:
Eighty-four Lisfranc injuries presenting at Oslo University Hospital between September 2014 and August 2015 were included. The diagnosis was based on radiologically verified injuries to the tarsometatarsal joints. Associations between radiographic findings and stability were examined.

Results: The incidence of Lisfranc injuries was 14/100,000 person-years, and only 31% were high-energy injuries. The incidence of unstable injuries was 6/100,000 person-years, and these were more common in women than men (P=.016). Intraarticular fractures in the two lateral tarsometatarsal joints increased the risk of instability (P=.007). The height of the second tarsometatarsal joint was less in the unstable injuries than in the stable injuries (P=.036).

Conclusion:

The incidence of Lisfranc injuries in the present study is higher than previously published. The most common mechanism of injury is low-energy trauma. Intraarticular fractures in the two lateral tarsometatarsal joints, female gender and shorter second tarsometatarsal joint height increase the risk of an unstable injury.

Level of Evidence: Level III, cross-sectional study.

Keywords: Lisfranc injury; Tarsometatarsal joint injury; Midfoot injury

1. INTRODUCTION

Lisfranc (tarsometatarsal joint) injuries are complex, and can lead to high morbidity and substantial disability if not adequately treated. [1–7] The incidence has been reported to be 1/60,000 person-years[5]; however, these injuries may be underreported as up to 24% are missed on primary radiographs.[8] An increased awareness of these injuries combined with increased use of MRI, CT scans, weightbearing radiographs and stress fluoroscopy to detect them, seem to have increased the incidence compared to that reported in previous publications.[2,9–14]

High-energy trauma (motor vehicle accidents, falls from height and crush injuries) has been reported to account for the majority of the cases.[4,5,11,15,16] Low-energy injuries are most often caused by axial and/or rotational forces on a foot fixed in equinus, and these injuries tend to be more subtle.[3,17,18]

The stability of the midfoot is provided by osseous and ligamentous structures. Injuries to these structures may cause instability and progress to displacement of the tarsometatarsal joints.[19] In the subtle Lisfranc injuries with no displacement on radiographs or CT scans, it can be challenging to determine the stability of the injury. Weightbearing radiographs and stress fluoroscopy have been advocated to reveal an occult instability, preferably with images of the non-injured foot for comparison [3,20–26]. Lisfranc injuries without detectable displacement on weightbearing radiographs or on stress fluoroscopy should generally be treated non-operatively, whereas for the unstable injuries anatomic reduction and stable fixation is recommended. [3–5,15,21,22,27,28] In the acute phase both stress fluoroscopy and weightbearing radiographs can be painful. Furthermore, the interpretation of these examinations are also often subjective and examiner dependent. CT scans can be useful in the evaluation of Lisfranc injuries and many patients will be subjected to a CT scan of their foot. Therefore, determining radiological predictors of instability on CT images can be valuable in improving diagnosis of these injuries.

The aim of this study was to survey the incidence, the most common mechanisms of injury and to evaluate radiological predictors of instability in Lisfranc injuries. The hypothesis was that Lisfranc injuries and especially low-energy injuries are more frequent than previously reported, and that CT scans can help predict instability.

2. MATERIALS AND METHODS

The study was approved by the Regional Ethics Committee (2014/853/REK) and the patients signed an informed consent form. Between the 1st of September 2014 and the 31st of August 2015 all patients with Lisfranc joint injuries treated at Oslo University Hospital (a level one trauma center) and Oslo Accident and Emergency Department were registered. A Lisfranc injury was defined as injury to tarsometatarsal joint with avulsion fractures, intra-articular fractures and/or displacement of tarsometatarsal joint. Injuries to the tarsometatarsal joint were identified using radiographs, CT scans, MRI, stress fluoroscopy and/or weightbearing radiographs. Patients with isolated fracture of the fifth metatarsal and patients with Charcot arthropathy were excluded from the study.

Demographic data were recorded at presentation, as well as mechanism of injury and clinical findings. To determine the incidence of Lisfranc injuries all patients referred for treatment from other hospitals were excluded and only the patients with a permanent address in the Oslo University Hospital catchment area were included. On January 1st 2015 the hospital had a local catchment population of 399 665.

High-energy injuries were defined as injuries caused by motor vehicle accidents (MVA), fall from height (>3 meters) and crush injuries. Low-energy injuries were fall from own height, twisting injury of the foot, falling down stairs, bike accidents, kicking into an object. Sports related injuries were categorized separately.

The diagnostic algorithm is presented in Figure 1. Ten patients did not have a primary radiograph when admitted, as they had already had a CT or MRI scan. In patients without joint displacement on the CT scan, a stress fluoroscopy of both injured and non-injured foot was performed 7-14 days after the injury. Stress fluoroscopy could be performed without anesthesia in the majority of the patients. If stress fluoroscopy was not possible due to pain, general anesthesia was applied. Weightbearing radiographs of both feet (AP, lateral and 30° oblique views) were also used for evaluation when the stress fluoroscopy was inconclusive regarding stability.

Radiographs and CT scans were analyzed using Syngo Studio VB36E (Siemens Healthcare GmbH, Erlangen, Germany). The images were evaluated by two foot and ankle consultants and one radiology consultant experienced in musculoskeletal imaging. Fractures were categorized as intraarticular, extraarticular or avulsion fractures. Joint displacement of 2 mm or more were registered. The Lisfranc injuries were defined as unstable if there was a displacement of ≥2 mm in a tarsometatarsal, intercuneiform or naviculocuneiform joint on any of the initial non-weightbearing radiographs, CT scans or weightbearing radiographs, or if the patient had a positive stress fluoroscopy with joint incongruity.

The second metatarsal base is recessed between the medial and lateral cuneiforms in a “mortise”. The medial and lateral depth of the Lisfranc mortise as well as the height of the second tarsometatarsal joint, were measured on the CT scans by the radiology consultant (Figure 2).

The findings on radiographs and CT scans were correlated to the fluoroscopically evaluated stability to reveal any radiographic predictors of instability. All patients with unstable Lisfranc injuries were recommended operative treatment, while the patients with stable injuries were treated with a below knee cast for 6 weeks and then examined with weightbearing radiographs of both feet.

Statistics

Descriptive statistical analyses were used to determine frequencies of categorical variables and the group mean and standard deviation of continuous variables. The independent samples t-test was used to compare group means for continuous variables and for categorical variables the odds ratio and Pearson Chi-square test was used. The correlation between fracture pattern and stability was assessed using logistic regression. The interrater reliability when evaluating fractures and dislocations was calculated using the intraclass correlation coefficient. The statistical analyses were performed using SPSS version 25 (IBM, Armonk, New York). A threshold of $p<.05$ was set for statistical significance.

3. RESULTS

3.1 Patient demographics

Eighty-nine Lisfranc injuries were registered prospectively during the one-year period. Eighty-four patients consented to participate in the study. One patient had bilateral Lisfranc injuries. There was an equal distribution between genders (Table 1). The mean age was 41.0 (range, 14-83) years and the men were on average 10 years younger than the women (36.0 vs 45.8, P=.05).

Fifty-four of the 89 patients with Lisfranc injury lived in the Oslo University Hospital catchment area and resulted in an incidence of all Lisfranc injuries of 14/100,000 person-years. Twenty-two of these patients had injuries with instability, resulting in an incidence for unstable Lisfranc injuries of 6/100,000 person-years.

3.2 Mechanism of injury

The mechanisms of injury are presented in table 2. High-energy mechanisms (motor vehicle accidents (MVA), falls from more than three meters height and crush injuries) accounted for 31% of the injuries. The single most common mechanism of injury was fall from own height / twisting injury of the foot, occurring in 31% of the cases. In 21% percent, the injuries were sports related.

3.3 Radiological assessment and stability

Seventy-four feet (87%) had a primary nonweightbearing radiograph and 21 (28%) of these radiographs were described as normal. All patients except one had a CT scan of their injured foot (84 feet), all with findings consistent with Lisfranc injury. The interrater reliability of evaluating the fractures and displacements on radiographs and CT scans, was 0.83 (95% CI, 0.81-0.84), determined with the intraclass correlation coefficient.

Thirty-eight (45%) Lisfranc injuries were defined as unstable and 47 (55%) were stable (Table 2). Joint displacement as a sign of instability, was mainly detected on CT scans (17 feet) or a positive stress fluoroscopy (14 feet) (Table 3). In one patient an increased diastasis between the medial and middle cuneiform was detected on weightbearing radiographs, this was not detected on the stress fluoroscopy. Two other patients had an instability that was overlooked on initial stress fluoroscopy, but detected on weightbearing radiographs at the 6 weeks follow-up.

The distribution of avulsion fractures, intraarticular fractures and extraarticular fractures is shown in table 4. The only fracture pattern on CT scans that was correlated to instability in Lisfranc injuries was an intraarticular fracture of the fourth and/or fifth tarsometatarsal joint (OR= 6.0, 95% CI= 1.6-21.5).

When evaluating the Lisfranc mortise measurements, an increased height of the second tarsometatarsal (TMT) joint in the feet with a stable injury compared to those with an unstable injury was observed (21.2 vs 20.1 mm, p= .04). The medial Lisfranc mortise depth was larger in the group with stable Lisfranc injuries compared to the unstable group (mean 7.3 vs 6.6 mm), but this finding was not statistically significant (p=.07). Women had more shallow mortise depths and lower TMT-2 heights compared to men (Table 5).

4. DISCUSSION

The most important findings of the present study are that we observed a higher incidence of Lisfranc injuries than previously reported in the literature, and that the majority of the injuries are low-energy or sports-related. Furthermore, intraarticular fractures of the lateral tarsometatarsal joints, female gender and a lower second tarsometatarsal joint height increase the risk of having an unstable Lisfranc injury.

In the present study, all Lisfranc injuries during a one year period were prospectively registered. The overall incidence of both stable and unstable Lisfranc injuries was 14/100,000 person-years, whereas the incidence of unstable injuries was 6/100,000 person-years. The incidence of Lisfranc injuries has been reported be 1/60,000 person-years or 0.2 percent of fractures based on older studies.[5,29,30] Recently Ponkilainen et al. published a CT based study where they retrospective examined all CT scans of midfoot fractures during a 5-year period. They found the CT based incidence of Lisfranc injuries to be 9.2/100,000 person-years. The findings of the present study and those of Ponkilainen et al. suggest that the incidence of Lisfranc injuries is probably higher than previously reported. The high incidence found in the present study may be caused by the prospective design, a higher awareness of these injuries and the use of more advanced diagnostic tools such as CT scans, MRIs, stress fluoroscopy and weightbearing radiographs, thereby also detecting the more subtle injuries.

We found high-energy trauma to be the cause of injury in only 31% of patients and low-energy trauma to be the most common injury mechanism. Numerous authors have reported Lisfranc injuries primarily being caused by high-energy trauma.[4,5,11,15] More recently, however, Renninger et al. found that 60% of the surgically treated Lisfranc injuries at their institution resulted from low energy trauma.[18] Ponkilainen et al. also reported the majority of Lisfranc injuries to be caused by low-energy trauma and only 36,5% of the injuries being caused by high-energy trauma mechanisms. [31] This emphasizes that one should have a high suspicion of Lisfranc injuries even in patients with midfoot pain after a low-energy trauma as these injuries may lead to severe disability if they are missed or treated inadequately. [32,33]

Evaluating the stability of Lisfranc injuries is essential in treating these injuries as nonoperative treatment is recommended in stable injuries and operative treatment in unstable injuries.[20,28,34] Occult instability in a Lisfranc injury can be detected by either weightbearing radiographs or stress fluoroscopy.[4,20,21] The stress fluoroscopy has been criticized for being subjective and examiner dependent.[26] On the other hand, Kaar et al. demonstrated in a cadaver study that stress fluoroscopy had better sensitivity in detecting instability compared to weightbearing radiographs.[24] Both stress fluoroscopy and weightbearing radiographs present a challenge in the acute setting, as they can be painful examinations. Since we delayed the stress fluoroscopy until 7-14 days after injury, we were able to perform the testing without anesthesia in most patients. However, two of the 49 Lisfranc injuries initially evaluated as stable after stress fluoroscopy had a positive weightbearing radiograph indicating midfoot instability on the 6 weeks follow-up. This emphasizes the importance of follow-up with weightbearing radiographs in patients with injuries that initially are evaluated as stable, as also recommended by Myerson and Cerrato.[17]

As both stress fluoroscopy and weightbearing radiographs are challenging to perform in the acute setting, identifying predictors of instability on CT scans could be very helpful in diagnosing these injuries. By comparing the CT findings to the stability of the injuries, we found that intraarticular fractures in the two lateral tarsometatarsal joints increased the risk of having an unstable Lisfranc injury. An avulsion fracture of the Lisfranc ligament (fleck sign) has in previous articles been interpreted as a sign of instability. [18,20] We were not able to correlate any other fracture pattern (including fleck sign) to the stability of the Lisfranc injuries.

Several authors have reported Lisfranc injuries to be more common in men compared to women.[1,4,5,15,22,35] In the current study the distribution between genders was equal, as also reported by both Crates et al. and Komenda et al. [16,27] We found, however, a higher proportion of unstable injuries in women. Also, women had a decreased Lisfranc mortise depth and second tarsometatarsal joint height compared to the men. Peicha et al. have previously reported that a shallow medial mortise depth is a risk factor for Lisfranc injuries, and this is also supported by Yu-Kai et al., who observed that women had a more shallow medial mortise depth and a shorter height of the second metatarsal base than men.[36,37] As the lateral aspect of the medial cuneiform is the origin of the interosseous and plantar part of the Lisfranc ligament and the medial and plantar aspect of the second metatarsal base is the attachment area, one might speculate that the feet with a deeper medial mortise and a higher second tarsometatarsal joint might have a broader and stronger Lisfranc ligament, and thereby a decreased risk of obtaining an unstable Lisfranc injury.[19]

The present study has some inherent weaknesses. First of all, a larger patient number would have increased study power. There is some degree of uncertainty regarding the epidemiological data, as some patients with Lisfranc injuries from the Oslo University Hospital population might have been treated elsewhere. This would lead to an underestimated injury incidence. Furthermore, we were not able to compare stress fluoroscopy with weightbearing radiographs, as most patients did not have weightbearing radiographs.

The strengths of the study include Oslo University Hospital being the primary trauma center in the region and Oslo A&E Department is the only public primary health care walk-in facility in Oslo. In addition, all patients were included in the study in a prospective manner when presenting with the injury, evaluated by an orthopaedic surgeon specialized in Foot and Ankle Surgery and a diagnostic algorithm was used. All patients, except one, had a CT scan of the injured foot. Over 90 percent of patients with stable injuries were followed up with weightbearing radiographs at 6 weeks, thereby any occult instability could be detected.

5. CONCLUSION

In the present study we observed a higher incidence of Lisfranc injuries than previously reported, and low-energy trauma was the most common mechanism of injury. Women had a shallower Lisfranc mortise than men and a higher proportion of unstable injuries. We also found that shorter second tarsometatarsal joint height and intraarticular fractures in the two lateral tarsometatarsal joints increased the risk of having an unstable Lisfranc injury.

Conflict of interest

The authors declare no potential conflicts of interests.

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REFERENCES

[1] Goossens M, Stoop N De. Lisfranc's fracture-dislocations: etiology, radiology, and results of treatment. Clin Orthop Relat Res 1983.

[2] Haapamaki V, Kiuru M, Koskinen S. Lisfranc Fracture-dislocation in PatientswithMultiple Trauma: Diagnosis with Multidetector Computed Tomography. Foot Ankle Int 2004;25:614–9. doi:10.1177/107110070402500903.

[3] Curtis MJ, Myerson M, Szura B. Tarsometatarsal joint injuries in the athlete. Am J Sports Med 1993;21:497–502. doi:10.1177/036354659302100403.

[4] Myerson MS, Fisher RT, Burgess AR, Kenzora JE. Fracture dislocations of the tarsometatarsal joints: end results correlated with pathology and treatment. Foot Ankle 1986;6:225–42. doi:10.1177/107110078600600504.

[5] Hardcastle P, Reschauer R, Kutscha-Lissberg E, Schoffmann W. Injuries to the tarsometatarsal joint. Incidence, classification and treatment. J Bone Jt Surg 1982;64–B:349–56.

[6] Faciszewski T, Burks RT, Manaster BJ. Subtle injuries of the Lisfranc joint. J Bone Jt Surg 1990;72:1519–22. doi:10.1016/j.pcad.2015.11.006.

[7] Wilppula E. Tarsometatarsal fracture-dislocation. LAte results in 26 patients. Acta Orthop Scand 1973;44:335–45.

[8] Haapamaki V V, Kiuru MJ, Koskinen SK. Ankle and foot injuries: analysis of MDCT findings. AJR Am J Roentgenol 2004;183:615–22. doi:10.2214/ajr.183.3.1830615.

[9] Ellis SJ, Yu JC, Johnson a H, Elliott A, O'Malley M, Deland J. Plantar pressures in patients with and without lateral foot pain after lateral column

lengthening. J Bone Joint Surg Am 2010;92:81–91. doi:10.2106/JBJS.H.01057.
[10] Raikin SM, Elias I, Dheer S, Besser MP, Morrison WB, Zoga AC. Prediction of midfoot instability in the subtle Lisfranc injury. Comparison of magnetic resonance imaging with intraoperative findings. J Bone Joint Surg Am 2009;91:892–9. doi:10.2106/JBJS.H.01075.
[11] Vuori JP, Aro HT. Lisfranc joint injuries: trauma mechanisms and associated injuries. J Trauma 1993;35:40–5. doi:10.1097/00005373-199307000-00007.
[12] Watson TS, Shurnas PS, Denker J. Treatment of Lisfranc joint injury: current concepts. J Am Acad Orthop Surg 2010;18:718–28.
[13] Myerson MS. The diagnosis and treatment of injury to the tarsometatarsal joint complex. J Bone Joint Surg Br 1999;81:756–63. doi:10.1302/0301-620X.81B5.10369.
[14] Stavlas P, Roberts CS, Xypnitos FN, Giannoudis P V. The role of reduction and internal fixation of Lisfranc fracture-dislocations: A systematic review of the literature. Int Orthop 2010;34:1083–91. doi:10.1007/s00264-010-1101-x.
[15] Kuo RS, Tejwani NC, Digiovanni CW, Holt SK, Benirschke SK, Hansen ST, et al. Outcome after open reduction and internal fixation of Lisfranc joint injuries. J Bone Joint Surg Am 2000;82–A:1609–18.
[16] Komenda GA, Myerson MS, Biddinger KR. Results of arthrodesis of the tarsometatarsal joints after traumatic injury. J Bone Jt Surg 1996;78:1665–76.
[17] Myerson MS, Cerrato RA. Current management of tarsometatarsal injuries in the athlete. J Bone Jt Surg 2008;90–A:2522–33.
[18] Renninger CH, Cochran G, Tompane T, Bellamy J, Kuhn K. Injury Characteristics of Low-Energy Lisfranc Injuries Compared With High-Energy Injuries. Foot Ankle Int 2017;38:964–9. doi:10.1177/1071100717709575.
[19] Solan MC, Moorman CT, Miyamoto RG, Jasper LE, Belkoff SM. Ligamentous restraints of the second tarsometatarsal joint: a biomechanical evaluation. Foot Ankle Int 2001;22:637–41.
[20] Seybold JD, Coetzee JC. Lisfranc Injuries: When to Observe, Fix, or Fuse. Clin Sports Med 2015;34:705–23. doi:10.1016/j.csm.2015.06.006.
[21] Nunley JA, Vertullo CJ. Classification , Investigation , and Management of Midfoot Sprains Lisfranc Injuries in the Athlete. Am J Sports Med 2002;30:871–8.
[22] Arntz CT, Veith RG, Hansen ST, Holt SK, Benirschke SK, Hansen ST, et al. Fractures and fracture-dislocations of the tarsometatarsal joint. J Bone Joint Surg Am 1988;70:173–81. doi:10.1097/00005373-197403000-00001.
[23] Lu J, Ebraheim N a, Skie M, Porshinsky B, Yeasting R a. Radiographic and

computed tomographic evaluation of Lisfranc dislocation: a cadaver study. Foot Ankle Int 1997;18:351–5.

[24] Kaar S, Femino J, Morag Y. Lisfranc joint displacement following sequential ligament sectioning. J Bone Joint Surg Am 2007;89:2225–32. doi:10.2106/JBJS.F.00958.

[25] Coss HS, Manos RE, Buoncristiani a, Mills WJ. Abduction stress and AP weightbearing radiography of purely ligamentous injury in the tarsometatarsal joint. Foot Ankle Int 1998;19:537–41.

[26] Shakked RJ. Lisfranc Injury in the Athlete. JBJS Rev 2017;5:e4. doi:10.2106/JBJS.RVW.17.00025.

[27] Crates JM, Barber FA, Sanders EJ. Subtle Lisfranc Subluxation: Results of Operative and Nonoperative Treatment. J Foot Ankle Surg 2015;54:350–5. doi:10.1053/j.jfas.2014.07.015.

[28] Weatherford BM, Bohay DR, Anderson JG. Open Reduction and Internal Fixation Versus Primary Arthrodesis for Lisfranc Injuries. Foot Ankle Clin 2017;22:1–14. doi:10.1016/j.fcl.2016.09.002.

[29] English T. Dislocations of the metatarsal bone and adjacent toe. J Bone Jt Surg 1964;46B:700–4.

[30] Aitken A, Poulson D. Dislocations of the tarsometatarsal joint. J Bone Jt Surg 1963;45–A:246–60.

[31] Ponkilainen VT, Laine H-J, Mäenpää HM, Mattila VM, Haapasalo HH. Incidence and Characteristics of Midfoot Injuries. Foot Ankle Int 2018:107110071879974. doi:10.1177/1071100718799741.

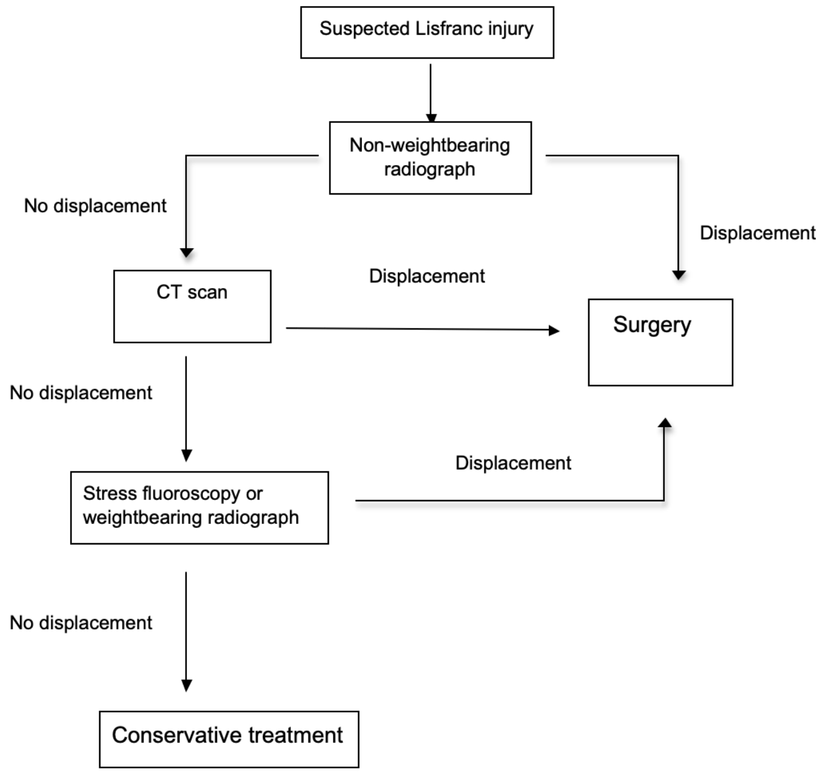
[32] Philbin T, Rosenberg G, Sferra JJ. Complications of missed or untreated Lisfranc injuries. Foot Ankle Clin 2003;8:61–71. doi:10.1016/S1083-7515(03)00003-2.

[33] Rammelt S, Schneiders W, Schikore H, Holch M, Heineck J, Zwipp H. Primary open reduction and fixation compared with delayed corrective arthrodesis in the treatment of tarsometatarsal (Lisfranc) fracture dislocations. J Bone Joint Surg Br 2008;Nov 2008:1499.

[34] Nunley JA, Vertullo CJ, Carolina N. Classification , Investigation , and Management of Midfoot Sprains Lisfranc Injuries in the Athlete 2002;30:871–8.

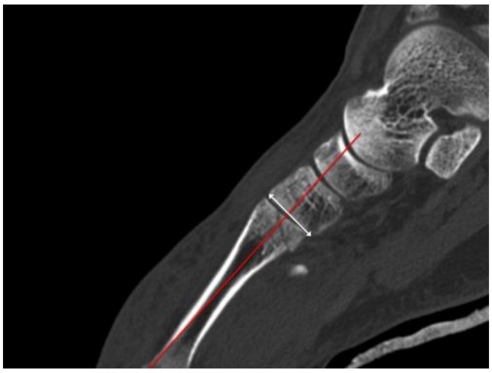
[35] Coetzee JC, Ly T V. Treatment of primarily ligamentous Lisfranc joint injuries: primary arthrodesis compared with open reduction and internal fixation. Surgical technique. J Bone Joint Surg Am 2007;89 Suppl 2:122–7. doi:10.2106/JBJS.F.01004.

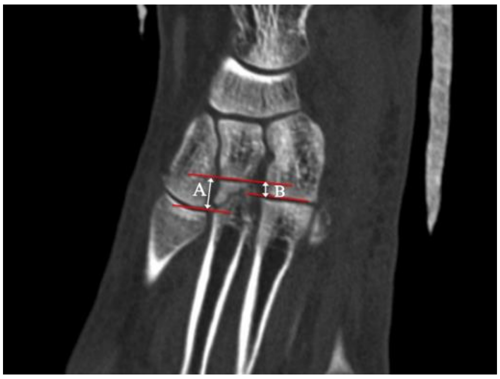
[36] Peicha G, Labovitz J, Seibert FJ, Grechenig W, Weiglein a, Preidler KW, et al. The anatomy of the joint as a risk factor for Lisfranc dislocation and fracture-dislocation. An anatomical and radiological case control study. J Bone Joint Surg Br 2002;84:981–5.
[37] Yu-kai Y, Shiu-bii L. The Journal of Foot & Ankle Surgery Anatomic Parameters of the Lisfranc Joint Complex in a Radiographic and Cadaveric Comparison. J Foot Ankle Surg 2015;54:883–7. doi:10.1053/j.jfas.2015.02.021.



Caption Figure 1

Diagnostic algorithm for suspected Lisfranc injuries. Displacement is defined as ≥2mm displacement of a tarsometatarsal, intercuneiform or naviculocuneiform joint on radiographs or CT scans, or obvious displacement on stress fluoroscopy.





Caption Figure 2a

CT scan sagittal plane, left foot. Height of the second tarsometatarsal joint (arrow). Red line indicating coronal plane centered in second tarsometatarsal joint (2b).

Caption Figure 2b

CT scan left foot, coronal plane centered in the second tarsometatarsal joint as shown in picture 2a. Distance A represent the medial Lisfranc mortise depth, and distance B represent the lateral Lisfranc mortise depth.

Table 1

Patient demographics

	Stable injury	Unstable injury	Total	P-value	Odds ratio
Mean age (SD)	38.4 (16.5)	44.2 (15.6)	41.0 (16.3)	0.10	
Gender (male/female)	29/18	13/25*	42/43*	0.016	OR=3.1 (1.3-7.6)
Side (right/left)	21/26	17/21	38/47	1.0	OR=1.0 (0.4-2.4)
Days to diagnosis	3.2 (7.8)	3.5 (9.7)	3.4 (8.7)	0.92	
Ipsilateral FA fx**	9	5	14	0.46	OR=0.6 (0.2-2.1)

* One female patient with bilateral unstable Lisfranc injuries

** Other ipsilateral foot and ankle fractures

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Table 2
Mechanism of injury

Mechanism of injury	**Lisfranc Injuries**		
	Stable	Unstable	Total
- Fall from own height/ twisting of foot	14	12	26
- Bike accident	2	2	4
- Fall down stairs	1	3	4
- Kicked into an object	2	1	3
- Sports related injuries	7	11	18
Soccer	*4*	*3*	*7*
Gymnastics	*2*	*2*	*4*
Martial arts	*0*	*3*	*3*
Windsurfing/kiting	*1*	*1*	*2*
Snowboard	*0*	*1*	*1*
Skateboard	*1*	*0*	*1*
- Motor vehicle accident	7	3	10
- Fall > 3 meters	3	3*	6
- Crush injury	10	1	11
- Unknown**	1	2	3
Total	**47**	**38**	**85**

*One patient with bilateral injuries

** Unknown due to alcohol intoxication

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Table 3
Detection of joint displacement

	No. of feet	Negative	Joint displacement detected
Primary radiographs (non-WB)	74	21*	4
CT scan	84	0*	17
Stress-test under fluoroscopy	67	45**	14
Primary weightbearing radiographs	19	17**	1
Follow-up weightbearing radiographs	30	28**	2
Sum			38

Weight-bearing radiographs were compared to the non-injured side.

CT scans and radiographs were registered as positive if there were any fractures (including minor avulsion fractures) or joint displacements.

* Negative in terms of no joint displacement or fracture (including small avulsion fractures)

** No joint displacement detected.

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Table 4
CT scan findings related to stability

	No. feet	Stable injuries	Unstable injuries	Odds ratio (95% CI)	P-value
CT scan	84	46	38		
"Fleck" sign	39	18	21	2.00 (.64-6.21)	0.23
Medial column					
No fracture	16	11	5	Ref	
Avulsion fractures	32	19	13	1.88 (.39-9.01)	0.43
Intraarticular fractures	35	15	20	2.51 (0.53-11.94)	0.25
Extraarticular fractures	1	1	0	NA	
Middle column					
No fracture	8	5	3	Ref	
Avulsion fractures	9	8	1	0.14 (0.01-2.15)	0.16
Intraarticular fractures	56	25	31	0.81 (.13-4.89)	0.82
Extraarticular fractures	11	8	3	0.45 (0.05-3.94)	0.47
Lateral column					
No fracture	36	26	10	Ref	
Avulsion fractures	2	0	2	NA	
Intraarticular fractures	31	9	22	5.95 (1.64-21.54)	**0.007**
Extraarticular fractures	15	11	4	1.13 (0.25-5.22)	0.87

Fracture patterns detected on CT scans related to stability of the Lisfranc injury.

Statistical significant finding highlighted. Ref= reference group. NA= not applicable

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Table 5
Lisfranc mortise measures related to instability

	Lisfranc injuries			**Gender**		
	Stable injuries	Unstable injuries	P-value	Male	Female	P-value
Medial mortise depth (mm)						
Mean (SD)	7.3 (1.8)	6.6 (1.7)	0.072	7.3 (1.9)	6.6 (1.6)	0.057
Lateral mortise depth (mm)						
Mean (SD)	3.6 (1.5)	3.7 (1.2)	0.785	4.0 (1.5)	3.3 (1.1)	**0.024**
TMT-2 height (mm)						
Mean (SD)	21.2 (2.3)	20.1 (2.4)	**0.036**	21.6 (2.3)	19.8 (2.1)	**0.001**

Feltkode endret

TMT-2 height = tarsometatarsal joint 2 height

Measurements are described in figure 2.