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Lisfranc injuries: an update

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Abstract Lisfranc injuries are a spectrum of injuries to the tarsometatarsal joint complex of the midfoot. These range from subtle ligamentous sprains, often seen in athletes, to fracture dislocations seen in high-energy injuries. Accurate and early diagnosis is important to optimise treatment and minimise long-term disability, but unfortunately, this is a frequently missed injury. Undisplaced injuries have excellent outcomes with non-operative treatment. Displaced injuries have worse outcomes and require anatomical reduction and internal fixation for the best outcome. Although evidence to date supports the use of screw fixation, plate fixation may avoid further articular joint damage and may have benefits. Recent evidence supports the use of limited arthrodesis in more complex injuries.

Keywords Lisfranc injury · Midfoot injury · Midfoot fracture · Midfoot sprain

Introduction

Lisfranc injury is an eponymous term, named after Napoleon's surgeon during the Napoleonic wars, and refers to an injury to the tarsometatarsal (TMT) joint complex of the midfoot. The TMT complex includes the TMT joints, the intermetatarsal ligaments and the associated intercuneiform joints. The injury may be purely ligamentous, bony or more commonly a combination of both. These range from undisplaced injuries to fracture dislocations of some or all of the TMT joints.

They are uncommon, accounting for 0.2 % of all fractures with an incidence of 1 in 55,000 people in the United States annually [2, 26]. This may be an underestimate, as up to one-third of injuries can be missed on initial review [48, 56, 61], and this is a common cause for litigation [11].

High-energy injuries, for example, motor vehicle accidents, are more common (58 %) than low-energy injuries, for example, fall from height (48 %) [73]. There are two main mechanisms of injury: either due to indirect forces (e.g. bending and twisting to the midfoot) or due to direct forces (e.g. crush injuries). Lisfranc injuries are 2–4 times more frequent in males, probably due to a higher participation in activities involving high-speed injuries [24].

Prompt identification and optimal management of these injuries is important as they often lead to degenerative arthritis, chronic instability, pain and disability.

Anatomy

The stability and function of the Lisfranc articulation is formed from the bony geometry of the three cuneiforms and cuboid proximally, and the five metatarsal bases distally linked together by the associated capsulo-ligamentous structures.

Osteology

The second metatarsal base is the "keystone" and is recessed in a mortise between the medial and lateral

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cuneiforms, whilst a "Roman arch" is formed by the wedge-shaped cuneiforms creating a transverse arch. This provides direct bony stability to the articulation, and a shallow second TMT joint mortise has been shown to be a positive risk factor for a Lisfranc injury [54].

The midfoot is usually described as being composed of three columns. The middle column between the second and third metatarsals, and the middle and lateral cuneiforms are the most rigid articulation. The medial column is made up of the navicular, medial cuneiform and the first metatarsal. Coronal motion in the medial column is minimal, but there is some movement in the frontal and sagittal planes (3°–4°) with dorsiflexion linked with inversion and plantarflexion with eversion [23]. It provides an effective lever arm during gait and experiences the largest forces during heel-rise phase of gait [64]. The lateral column, consisting of the cuboid and the fourth and fifth metatarsals, is more mobile with up to 10° movement in both the sagittal and coronal plane. This mobility would help explain why instability of the lateral column after injury may be tolerated and development of symptomatic lateral column arthritis is uncommon [23].

Ligaments

It is becoming more obvious that the "Lisfranc injury" is actually a spectrum of injuries of the tarsometatarsal complex [14]. A detailed review of the ligamentous structures supporting the articulation is important in order to understand the varying degrees of instability that may occur—particularly with the subtle injuries.

There is much variation in the literature regarding the anatomy of the "Lisfranc ligament", and it may be better to refer to the "Lisfranc complex" [53, 54]. Within this complex are the weaker dorsal ligaments, the plantar Y-shaped ligament from the medial cuneiform to the bases of the second and third metatarsals and the strongest, a more dorsal interosseous ligament, between the medial cuneiform and the base of the second metatarsal (usually referred to as the "Lisfranc ligament") [72]. There are interosseous ligaments that connect the second through to the fifth metatarsal bases, both dorsal and plantar and middle to medial cuneiform, but it is important to remember that there is no transverse metatarsal ligament between the first and second metatarsal bases or to the medial cuneiform. The dorsal ligaments provide only a third of the strength of the Lisfranc ligament and are even weaker than the remaining plantar ligaments [21, 46, 72], which may explain the preferential dorsal direction of dislocations. Secondary stabilisers of the midfoot include the plantar fascia, the peroneus longus and the intrinsic muscles [34, 53].

Panchbhavi et al. [52] in their cadaveric study showed a 1.3-mm mean displacement between the intact Lisfranc ligament model and the cut loaded model. Their three-dimensional model demonstrated that the rotational effect between the first and second metatarsals led to only a modest dorsal or plantar displacement. However, the residual incongruency may lead to increased degenerative changes [34].

Sequential division within the Lisfranc ligament complex has demonstrated that both the intra-osseous ("Lisfranc ligament") and the plantar ligament between the second and third metatarsals need to be sectioned before transverse instability (defined by widening between the medial cuneiform and the second metatarsal base) is seen, whilst longitudinal instability (widening between the medial and intermediate cuneiforms) was produced by additional division of the interosseous ligament between the medial and middle cuneiforms [34, 53]. Clinically, failure of the intra-osseous ligament frequently leads to an avulsion fracture at the base of the second metatarsal or medial cuneiform and may be seen on plain radiographs as a "fleck sign".

Classifications

Quenu and Kuss originally described the classification of Lisfranc injuries in 1909 based on their three-column concept and separated injuries into homolateral, isolated and divergent [73]. Hardcastle et al. [30] and then Myerson et al. [48] modified this, with the latter being the most common classification system used dividing injuries into three categories (Fig. 1) [48, 77]. Chiodo and Myerson [13] have since then introduced a further classification which may provide more prognostic information based on injuries to the articulation of the three columns. Outcomes are worse for injuries around the base of the second MT with regard to the development arthritis, whilst the medial and lateral columns appear to tolerate incongruity better [36].

The more subtle lower-energy injuries have been classified by Nunley and Vertullo [50], based on clinical examination, comparative weight-bearing radiographs and bone scans (Fig. 2). In Stage I injuries, patients have restrictive midfoot pain and are not able to participate in sport, and weight-bearing anteroposterior radiographs show no displacement, but positive bone scans. In Stage II injuries, radiographs show a diastasis of 1–5 mm, but no loss of midfoot arch on the lateral film. In Stage III, radiographs show a diastasis of greater than 5 mm and loss of midfoot arch height as measured by reduced distance between the fifth metatarsal and medial cuneiform on the lateral radiograph [50]. They recommend non-operative treatment for Stage I (undisplaced) injuries, anatomical reduction and fixation for Stage II (diastasis with no arch height loss) and Stage III (diastasis with arch height loss) injuries.

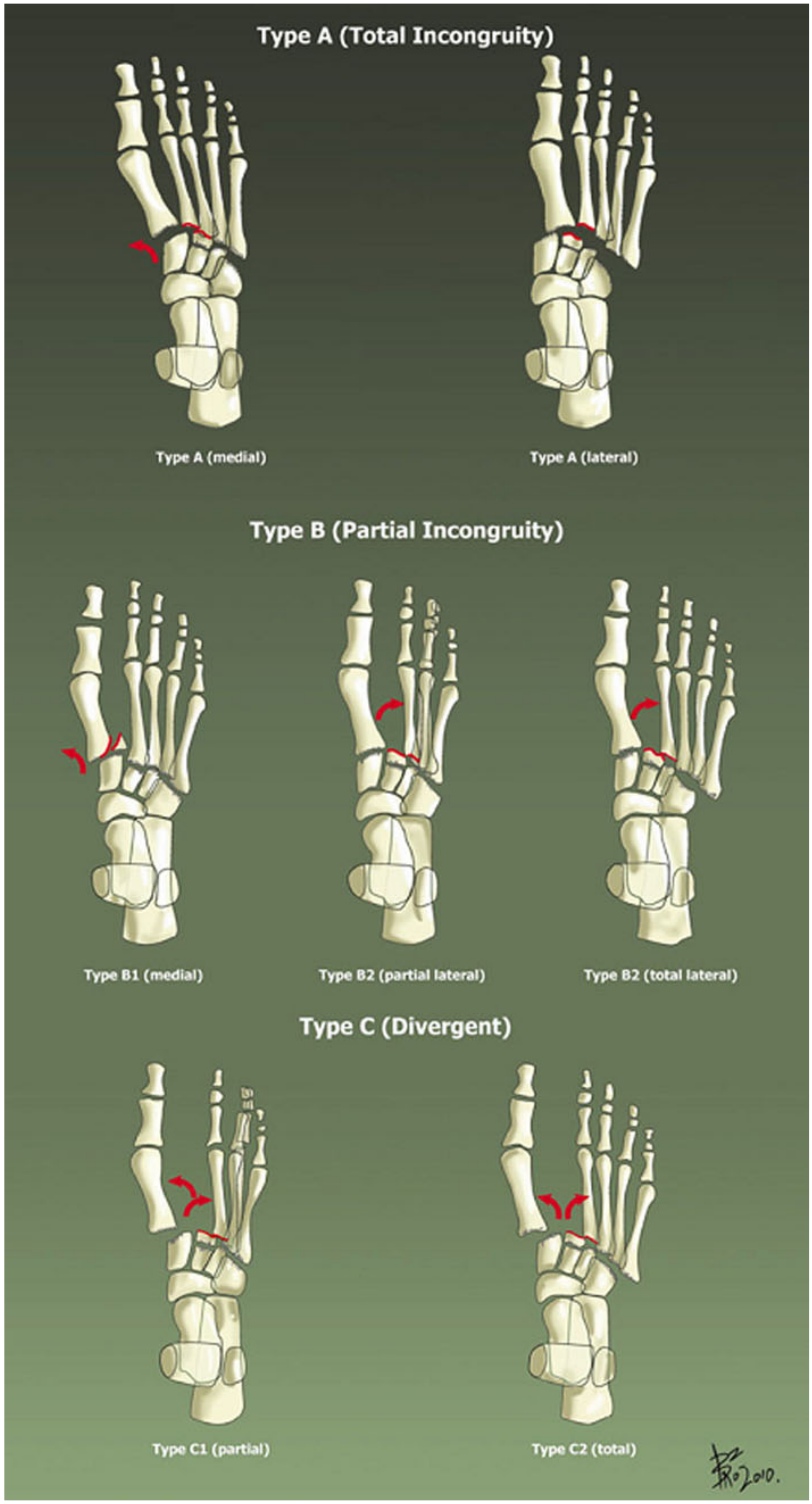

Fig. 1 The Myerson's Classification of Lisfranc Injuries [48] (From Stavlas et al. [73]. "Fig. 3 Myerson et al.'s Classification of Lisfranc fracture dislocations"; with kind permission from Springer Science and Business Media)

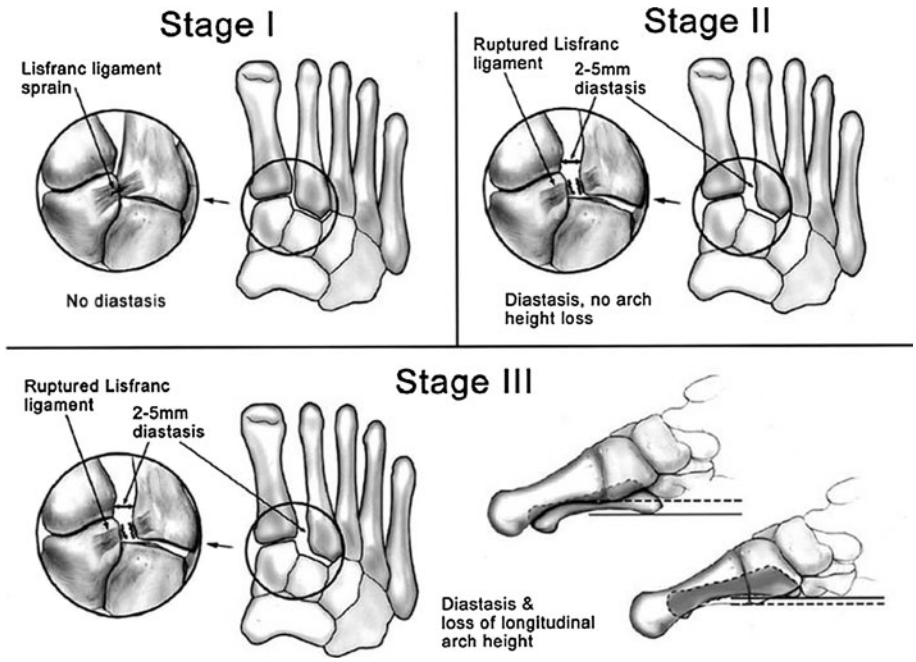

Fig. 2 The Nunley and Vertullo's Classification of Lisfranc subtle injuries [50] (From Nunley and Vertullo [50]; "Fig. 1. Midfoot sprain classification system. Stage I is a sprain to the Lisfranc ligament with no diastasis or arch height loss seen on radiographs but increased uptake on bone scintigrams. Stage II sprains have a first to second intermetatarsal diastasis of 1–5 mm because of failure of the Lisfranc ligament but no arch height loss. Stage III sprains display first to second intermetatarsal diastasis and loss of arch height, as represented by a decrease in or inversion of the distance between the plantar aspect of the fifth metatarsal bone and the plantar aspect of the medial cuneiform bone on an erect lateral radiograph"; with kind permission from Springer Science and Business Media)

However, there is a discrepancy between their descriptive and figurative classification, with Stage II injuries classified as a diastasis of 1–5 mm, whilst their illustration states this as 2–5 mm; Stage III injuries are classified as a diastasis of >5 mm with loss of midfoot arch height, but is illustrated as having a 2–5 mm diastasis with loss of longitudinal arch height. This discrepancy leads to inconsistency in how the classification is applied by others [14, 65].

Chris Coetzee [14] also used this classification but pointed out that the "Lisfranc injury is a part of a very wide and poorly defined spectrum of injuries" and proposed a treatment algorithm dependent on whether the injury was one of an incomplete or complete ligamentous disruptions (Table 1).

Presentation and examination findings

A significant proportion of these injuries are missed or diagnosed late. The high-energy injuries are more obvious, and the history and clinical findings are very apparent. The low-energy injuries are harder to detect with more subtle clinical signs and the history less traumatic, giving a lower index of suspicion. This is especially true of athletes, who will often underestimate the extent of their injury and try to walk it off.

The patient will complain of midfoot pain and discomfort and may have a sensation that the foot is not supportive. The presentation of a painful swollen midfoot following foot trauma should alert the physician to this injury. Examination will reveal a swollen midfoot with tenderness and pain on passive movements of the midfoot [19]. The plantar arch ecchymosis (Fig. 3) is highly suggestive of such an injury [66], and dorsal bruising may occur later [38]. Comparison with the contralateral foot is essential, but bilateral injuries do occur, particularly in windsurfers and parachutists [38]. The "gap sign" (Fig. 4) has been described where there may be separation between the great and second toes [20].

Although a vascular injury is uncommon, compartment syndrome may occur as can injury to the deep peroneal nerve [65, 81].

Imaging

Plain radiographs

Initial imaging is with plain radiographs, anteroposterior (AP), 30° oblique and lateral films. Because of the obliquity of the joints and the close geometry, interpretation can be difficult—a recent radiographic study suggests that a

Table 1 Definition of Lisfranc injuries depending on the degree of ligamentous disruption used by Chris Coetzee [14] for his management algorithm

Definition of Lisfranc injury depending on degree of ligamentous disruption
Incomplete ligamentous disruption
a) Stage 1: Less than 2-mm diastases. No arch collapse
b) Stage 2: >2–5-mm diastases. No arch collapse
c) Stage 3: >2–5-mm diastases. Medial longitudinal arch collapse
Complete ligamentous disruption
a) Without significant intra-articular fractures
b) With significant intra-articular comminution

Fig. 3 The plantar ecchymosis is a sign highly suggestive of a Lisfranc injury [66]

Fig. 4 The “gap sign” seen on the right foot is indicative of separation between the great and second toes [20]

craniocaudal angle of 28.9° for the AP view will optimise visualisation of the joints in the majority of patients [62]. Weight-bearing views and abduction-pronation stress views can identify subtle injuries, when non-weight-bearing films are normal [50]. This is often too painful to perform acutely, and either a delayed examination or even a regional local anaesthetic ankle block may be helpful. If the diagnosis remains uncertain, examination under anaesthesia with stress views can be performed.

A number of radiographic findings that are consistent with a Lisfranc injury have been described (Table 2 and Fig. 5a, b, c). These include the “fleck” sign which indicates avulsion of the Lisfranc ligament from the medical cuneiform of the base of the second metatarsal [75] and a separation of 2 mm between the base of the first and second metatarsals on the AP view [75] or a greater than 1-mm difference from that of the contralateral uninjured foot [27].

However, plain films are limited by their two-dimensional representation of the injury, and accurately measuring a distance of less than 2 mm is problematic [40]. Cadaveric studies have shown that a diastasis of 1.3 mm may be significant in differentiating between an intact and a torn Lisfranc ligament [52], and plain radiographs are not be reliable in detecting diastases of less than 2 mm.

The first–second intermetatarsal distance is variable in the normal population with a range of 2.6–3.0 mm [16, 27, 57]. Therefore, in these subtle cases, it is important to measure this in comparison with the uninjured side. A comparison view should also include assessment of any sagittal displacement on the lateral weight-bearing film and any intercuneiform separation [20].

Although full weight-bearing and stress radiographs may be useful [18], their effectiveness in demonstrating diastasis is variable due to the inability to reproduce the forces and no standardised criteria exist [34, 50].

Multiplanar imaging

CT scanning with multiplanar reconstruction provides a more accurate assessment of the TMT joint complex and will identify minor subluxations and subtle fractures not seen on plain radiography. It is also a valuable pre-operative planning tool [29, 35, 63]. The scans are naturally non-weight-bearing and are not as sensitive as in undisplaced

Table 2 Plain film radiographic findings consistent with a Lisfranc injury

Plain film radiographic findings consistent with a Lisfranc injury
Diastasis >2 mm between the base of the first and second metatarsals on the AP view [75], or a greater than 1 mm difference than that of the contralateral uninjured foot [27] (Fig. 5a)
Loss of alignment between the medial border of the second metatarsal and the medial border of the medial cuneiform [28]
Loss of alignment between the medial border of the fourth metatarsal and medial border of the cuboid on the oblique view [71, 75]
Flattening of the longitudinal arch and/or loss of alignment between the plantar aspect of the fifth metatarsal and the medial cuneiform on the lateral view [27, 74, 80] (Fig. 5c)
Avulsion of the Lisfranc ligament represented by the “fleck” sign on the AP view [75] (Fig. 5b)

Fig. 5 Plain film radiographic findings consistent with a Lisfranc injury. **a** illustrates widening more than 1 mm compared to the normal *left side* of the space between the bases of the first and second metatarsal bases on the AP weight-bearing view. The “fleck sign” is pointed out by the *white arrow* in **b**, whilst flattening of the longitudinal arch is shown in **c**

injuries [23]. Simulated weight-bearing CT scanning is possible, mimicking 50 % of weight-bearing [51], and can provide adequate stresses to depict an injury [52].

MR scanning is particularly valuable in undisplaced or minimally displaced injuries where plain radiographs and CT scans may be normal. MR may identify bone oedema or injury to individual ligaments [31, 35, 57, 58]. MRI has a sensitivity and predictive value of 94 % in diagnosing instability, by identification of disruption of the Lisfranc ligament complex [60].

Management

The goals of treatment are to restore the anatomy of the midfoot and hence its function, preventing later arthritis and disability. Arthritis is the most common complication and occurs to some degree in up to half the cases [73]. The risk of post-traumatic arthritis is greater when the injury is unrecognised or partially treated, when the anatomical reduction is not adequate and when it is a purely ligamentous injury [63, 73, 77]. A delay of surgical treatment of more than 6 months and an underlying compensation claim have been associated with a poorer outcome [8].

Stage 1: Stable injuries

The current evidence suggests that stable Stage I (Nunley and Vertullo) injuries can be successfully managed non-operatively and even athletes are able to return to their sporting disciplines. Satisfactory outcomes have been reported with a non-weight-bearing cast for 6 weeks (93 % excellent results) or with immediate weight-bearing and an orthotic device [45, 50, 70].

Unstable Stage 1 and displaced Stage 2/3 injuries

Unstable injuries on screening and displaced (2–5 mm) injuries have poor results with non-operative treatment in both athletic and non-athletic patients [45, 50, 70].

Operative management

Dorsolateral displacement of the second MT base of 1–2 mm reduces the TMT joint contact area by 13.1–25.3 % [25]. Several studies have shown that anatomical reduction provides better outcomes than non-anatomical reduction [4, 30, 37, 65], with anatomical reduction achieving good/excellent results in 50–95 % of patients, compared to 17–30 % of patients with non-anatomical reductions.

Closed reduction and percutaneous surgery

Closed reduction and K-wire fixation may be performed for definitive fixation [55, 61, 76], but biomechanical evidence shows that screw fixation provides better stability of the medial and middle columns [4, 37, 39]. This also reduces pin-site infection and K-wire migration, as well as the risks of re-displacement and re-dislocation when K-wires are removed early [4, 48]. Screw fixation (Fig. 6) is therefore the preferred method of fixation except for the lateral column which may be stabilised satisfactorily with K-wire fixation [73]. Concerns about inaccurate reduction and interposed tissues with percutaneous fixation have led to the recommendation for open reduction [4, 5].

Open surgery

A number of surgical approaches have been described, using two or three dorsal longitudinal incisions [4, 23, 24] or a transverse incision [43, 79]. The concern with the transverse approach, which may provide better access, is disruption to the skin blood supply. To address this, a modified transverse approach has been described; the incision is made in a zone proximal to the arcuate artery and distal to the lateral tarsal artery with some evidence that an increase in wound problems is not an issue [79]. Lui [41] has also described an arthroscopic approach.

Fig. 6 Screw fixation for a Lisfranc injury

Biomechanics of fixation

A cadaveric study has shown that the use of a 3.5-mm screw can damage a significant percentage of the TMT joint's articular cartilage [3] with additional thermal injury likely in vivo. Dorsal plating (Fig. 7) has been shown to have similar stability to trans-articular screws [3, 68], and plantar plating exhibits even better stability [44, 68]. The availability of locking plates may also lead to a more stable fixation [9], avoid further damage to the joint, can span complex comminuted fractures and avoid the problem of having to remove any intra-articular fragments in case of metalwork breakage [5, 37]. The further development of low-profile plates has addressed issues of soft tissue irritation. Recent studies report adequate outcomes [15, 59, 82], but more data are required to confirm this.

Bioabsorbable (e.g. polylactide) screws have also been advocated to avoid the need for screw removal [23], but concerns with regards to possible loss of fixation and articular damage when these screws degrade have been raised [3].

A suture-endobutton fixation (Tightrope^{TM}, Arthrex$^{®}$) has also been described [6, 17]. This is placed along the path of the Lisfranc ligament (medial cuneiform to second metatarsal base). Studies on cadavers have shown increased diastasis with suture-button compared to a 4.0-mm cannulated screw [1], which raises concerns about the adequacy of using this type of fixation. Other concerns include the potential of creep and elongation of the suture and its cost [5].

Fig. 7 Radiograph illustrating the use of dorsal plating to manage a Lisfranc injury

Post-operative protocol and removal of fixation

Protection after fixation is recommended for at least 6 weeks [73]. The metalwork is frequently symptomatic and may require removal in up to 16 % of cases [37, 42, 67]. There are concerns regarding early removal of fixation and subsequent loss of reduction which has been reported after removal at 3 months [42]. However, more recent studies have shown no loss of alignment with removal at 8 weeks [61].

Authors' preferred technique

Open surgery is recommended where possible, with primary fixation using dorsal plates to avoid further articular damage. The sequence of surgery normally starts with the second TMT joint, and this is reduced and stabilised with a dorsal plate. Diastasis between the medial and middle columns is reduced and then held with a screw between the medial cuneiform and second metatarsal–intermediate cuneiform. The midfoot is then carefully reassessed to identify remaining instabilities, including the naviculocuneiform joints. If unstable, the first and third TMT joints are treated with dorsal plates, and the fourth and fifth joints are reassessed and, if necessary, stabilised with K-wires. Naviculocuneiform injuries are stabilised using longer plates to cross these joints.

After 2 weeks in a back-slab with strict elevation, patients are mobilised in a boot, non-weight-bearing until 6 weeks and then partial weight-bearing until 12 weeks post-operatively when they may bear weight fully. The boot is removed at 16 weeks, and an orthotic is provided to support the midfoot whilst walking in normal shoes. K-wires are removed at 6 weeks, and if a screw is placed across the medial cuneiform to second metatarsal or a plate to the first TMT joint, then these are routinely removed at 12–14 weeks; otherwise, metalwork is left in situ unless it becomes symptomatic.

In cases of significant comminution or displaced ligamentous injury, primary arthrodesis is recommended to provide adequate long-term outcomes and reduce the need for further surgery to remove metalwork.

Arthrodesis

In cases with significant articular injury and comminution, post-traumatic arthritis is more likely to develop and a small number of studies have shown primary arthrodesis to have better outcomes [14].

Arthrodesis has also been recommended for purely ligamentous injuries (Fig. 8), which also have worse outcomes [37]. Ly and Coetzee in their randomised controlled trial of 41 patients with isolated acute or subacute injuries, with a mean follow-up of 42.5 months, showed that patients managed with arthrodesis were able to reach 92 % of their subjective pre-injury level of physical or sports activity in contrast to only 65 % of those who underwent open reduction and internal fixation (ORIF). Although the pre-injury level of activity was not made clear, those who underwent ORIF also demonstrated worse American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot Scale scores, with 75 % of patients losing correction and developing degenerative changes [42].

Mulier et al. [47] compared ORIF (16 patients) with partial fusion (five patients) and complete fusion (including the lateral column; six patients) in severe Lisfranc injuries. At 30 months, patients with complete fusions had more pain than both the fixation and partial arthrodesis groups. The fixation and partial fusion groups had similar outcome scores (Baltimore Painful Foot Score). The complete fusion subjects also showed a greater amount of forefoot stiffness, loss of metatarsal arch and sympathetic dystrophy compared to the others. The worst results were seen in the complete fusion patients, and it was felt that this was due to the stiffening of the relatively mobile lateral column. Despite similar functional scores in the fixation and partial arthrodesis groups, 94 % of the ORIF patients had degenerative changes in plain radiographs. The authors, therefore, felt that as a large proportion of such patients would need an arthrodesis at a later stage, early partial arthrodesis would be a better option [14].

Fig. 8 Radiographs illustrating the use of primary arthrodesis for managing a significant Lisfranc injury

Missed injuries

Significantly worse outcomes have been shown when operative treatment was delayed for over 6 months, and primary arthrodesis should be considered if diagnosis is delayed for longer than 3 months [8]. A secondary corrective fusion is useful in patients with a missed Lisfranc fracture dislocation and those with post-traumatic degenerative changes as a salvage operation and can provide good pain relief and improvements in function [32, 33, 36, 69].

Timing of surgery

The midfoot has little subcutaneous connective tissue, and therefore, it is wise to delay surgery for 1–2 weeks to allow for recovery of the soft tissues and to avoid wound complications. This delay in surgery does not appear to affect outcomes [7, 23, 37].

There is also a risk of compartment syndrome, with symptoms often masked by the normal swelling and pain associated with TMT joint injuries. This requires a high index of suspicion, especially in the high-energy injuries, and early fasciotomies may be necessary [23].

Management of open injuries

The management of open injuries should follow the general principles of surgical debridement, antibiotic and tetanus cover, with secondary soft tissue cover as necessary. There are few publications on these difficult injuries. Nithyananth et al. [49] retrospectively reviewed 13 patients with Grade IIIa or IIIb injuries (Gustilo Anderson Classification) with a mean follow-up of 56 months. K-wire fixation was used and external fixator in four patients. There was no loss of alignment on plain radiographs, and autofusion occurred in 10 cases. Good to excellent outcomes were noted in 9 of 13 patients, and all but two returned to their pre-injury occupation. It was noted that anatomical reduction was not possible in almost half of the patients due to the severity of injury. Chandran et al. [10] noted a higher incidence of complications in 11 patients of severe open injury treated with uniplanar external fixation. At the 1-year follow-up, all patients had a functional result and only two pin-site infections were observed, with radiographic union seen in all fractures, and only two cases showed mild incongruence in the joints. Nevertheless, only seven patients were able to walk comfortably and six to stand on tiptoe comfortably. A significant proportion (64 %) had significant arch deformity, and only six patients had good ankle range of movement, with all patients having some degree of stiffness of the subtalar or midfoot joints and their metatarsophalangeal joint.

Outcomes

Both the significance of the injury and the surgery contribute to a number of short-term complications such as compartment syndrome, infection, neurovascular injury, wound problems and deep vein thrombosis.

In the long term, the major concern is the development of post-traumatic arthritis in the midfoot, flat foot deformity and instability [78]. However, despite radiographic degenerative changes developing in almost half (49.6 %) of such patients [73], there is weak correlation between the extent of such arthritic changes reported and symptoms and not all patients are symptomatic enough (7.8 %) to require an arthrodesis [73].

Athletic patients with Stage I–II injuries have been able to return to sports activity as early as 12–14 weeks on average with operative [50] or non-operative treatment [70]. Surgical treatment does not appear to shorten this time frame [45, 50, 70], but can achieve over 90 % excellent results [50]. Stage III injuries are fortunately uncommon in the athletic population, as outcomes are poor, and a low rate of return to high-level competition was shown in female gymnasts with only five Lisfranc fracture-dislocation athletes being able to return to full competition [12]. In a study of 15 elite soccer and rugby players managed surgically for ligamentous (8 athletes) and bony (7 athletes) Lisfranc injuries, only one athlete with a purely ligamentous injury had to retire. All others were able to go back to training at an average of 20.2 weeks and returned to full competition at 25.6 weeks. Those with purely ligamentous injuries were able to return to training earlier. In this cohort, injuries were surgically managed by screw fixation between the medial cuneiform and base of second metatarsal, whilst bridging plates were applied dorsally across any unstable TMTJ joints of the medial or middle columns. Metalwork was removed at 12–16 weeks except when an arthrodesis was performed [22].

Proposed algorithm for treating Lisfranc injuries

Lisfranc classifications have been shown to be consistently unreliable in providing a management plan or predicting outcome [48, 77]. Nunley and Vertullo [50] in their classification of athletic injuries made an important contribution in defining and managing such injuries. However, as stated earlier, their classification has flaws. These are descriptive regarding the stages and severity of displacement. More recent research supports the fact that the more subtle injuries may be under-treated:

1. Nunley and Vertullo [50], building on the findings of Faciszewski et al. [27], demonstrated that significant sagittal displacement can occur in the absence of obvious transverse displacement, with an adverse outcome in such injuries. Recognising this, they included such a dorsal displacement as a defining factor in their Stage III of their classification [50].
2. Davies and Saxby in describing their "gap sign" pointed out the possibility of an isolated disruption of the articulation at the intercuneiform joint between the medial and middle cuneiforms in the absence of an obvious metatarsophalangeal diastasis, as reported by others [20, 83]. As part of operative management, it is important to assess the stability of this joint, as failure to address this instability may have an adverse effect on outcome [20].
3. A cadaveric biomechanical study demonstrated that both the interosseous "Lisfranc" ligament and the plantar ligaments between the medial cuneiform and second and third metatarsals needed to be sectioned before transverse instability was observed [34]. Longitudinal instability was seen when both the interosseous "Lisfranc" ligament and intercuneiform ligaments (medial to middle) were sectioned.
4. The same authors also found that in the absence of interosseous and plantar ligaments between the first and second rays, weight-bearing radiographs showed a decrease in the TMT diastasis. They postulated that this was due to a "tie-rod" effect of the plantar fascia acting in a truss-like manner [34].
5. Studies have shown that dorsolateral displacement of the second MT base of 1–2 mm will reduce the TMT joint contact area by up to 25 % [25]. This is poorly seen on plain radiographs and could lead to post-traumatic arthritis.
6. The classical understanding of these injuries focussed on the Lisfranc ligament and lateral or coronal plane displacements of the TMT joints. This was too simplistic and did not address the wider pattern of injury. Recent studies have shown the complexities of these injuries, that they affect a number of joints and that the displacements are in multiple planes which are poorly assessed by plain radiography. Multiple authors have commented that anatomical reduction and stable fixation lead to better outcomes [4, 39, 48, 63, 69, 73, 77].

Based on this evidence, it is suggested that these injuries are treated not only according to their degree of displacement but also according to their stability and potential to displace further. Based on the available clinical and biomechanical studies, the following assessment as a guideline for management of these injuries is recommended:

- >1-mm displacement in any plane affecting the medial three TMT joints, intercuneiform or naviculocuneiform joints on plain radiography or CT or MRI
- evidence of complete Lisfranc ligament injury: "fleck sign" on X-ray or CT, or disruption on MRI
- displacement on stress views or weight-bearing views.

If initial studies do not show an obvious injury, an MR scan is performed and weight-bearing plain films of both

Table 3 Our algorithm of managing Lisfranc injuries

Type	Clinical & imaging findings	Management
Type I	Stable injuries	Non-operative management
	Tender Lisfranc region on examination	Initial protective period of 2 weeks in a non-weight-bearing cast or boot. Re-examination at 2 weeks
	No displacement on initial plain AP and lateral radiographs (as described below) and on weight-bearing radiographs at 2 weeks	Absence of tenderness and any diastasis on repeat weight-bearing radiographs confirms stability
	No displacement or "fleck sign" on CT (in comparison with uninjured side)	Protection in a weight-bearing boot with orthotic support for 4 weeks and continued support in shoes for 3 months. Return to activities after 6 weeks as tolerated
	Positive MRI scan with No displacement or No complete avulsion of Lisfranc ligament	
	Normal stress (abduction/adduction) tests if deemed necessary	
Type II	Unstable injuries	Fixation* or Limited fusion as below
	Tender Lisfranc region on examination	*Fixation by open reduction is recommended. Percutaneous approach if the displacement reduces completely on non-weight-bearing films (intra-operative assessment may be considered)
	Any of:	
	>1-mm displacement on weight-bearing AP or lateral radiographs or CT/MRI scan (compared with uninjured side)	Non-weight-bearing (NWB) cast/boot 6 weeks and Partial weight-bearing (PWB) removable boot for 6 weeks, with orthotic
	>1-mm separation of medial intercuneiform joint on weight-bearing AP or lateral radiographs or CT/MRI scan (compared with uninjured side)	Non-weight-bearing (NWB) rehabilitation at 6 weeks (swimming, water running, cycling)
	Presence of "fleck sign" on radiographs or CT scan	WB rehabilitation at 12 weeks and orthotics in shoe for 3 months
	Positive MRI scan with displacement or complete avulsion of Lisfranc ligament	Return to training at 16 weeks if possible
	Abnormal stress (Abduction/Adduction) tests >1-mm separation compared with other side	
	(A) Bony injury with minimal comminution (large Lisfranc ligament avulsion fragment)	*Fixation* with the use of dorsal locking plate for medial and middle columns. Screw fixation medial cuneiform to second metatarsal. Use of K-wires for lateral column if displaced (remove K-wires at 6 weeks)
		Consider removal of plates and screw after 12–16 weeks
	(B) Purely ligamentous injury	*Limited fusion* Consider isolated screw fixation medial cuneiform to second metatarsal. Consider removal of this screw at 16 weeks
	(C) Significant comminution/displacement, high-energy injury	*Limited fusion* combined with dorsal plating of less injured articulations
	(D) Open injury (Gustillo Anderson Grade II/III)	Surgical debridement. Reduction and K-wire fixation, secondary soft tissue cover and use of external fixator as necessary. Consider delayed fixation or fusion if soft tissues settle

feet are repeated at 2 weeks to exclude instability. If there are still concerns, stress views are performed under anaesthesia with preparation to operate if needed.

Injuries can be classified into Stable (Type I) and Unstable (Type II) injuries with subdivisions (A–D) indicating recommended fixation methods (Table 3).

The lack of high-quality studies with regard to the management of such injuries has been reflected in the limited findings of meta-analysis reviews [73] and is a direct result of both the rarity and the variation in the presentation, the assessment and the management of such injuries. We believe that our algorithm, based on the available clinical and biomechanical studies, can help in their initial assessment and management.

Conclusions

Lisfranc injuries are a spectrum of injuries of the tarsometatarsal joints that disrupt the midfoot from the forefoot. They range from subtle ligamentous sprains often seen in athletes to fracture dislocations, usually a result of a high-energy injury. Such injuries are often missed, so accurate and early diagnosis is important to optimise treatment and minimise long-term disability. Whilst in undisplaced injuries non-operative treatment gives excellent results, displaced injuries require anatomical reduction and internal fixation for an improved outcome. Undisplaced injuries may be unstable and require temporary fixation to stabilise them. Although evidence to date supports the use of screw fixation, plate fixation may avoid further articular joint damage and may have benefits. There is evidence that in more complex and severe injuries, limited arthrodesis may provide a better outcome.

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