(iii) Tarsometatarsal injuries—Lisfranc injuries

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Summary

Lisfranc injuries are relatively uncommon injuries but with increasing motor vehicle use their incidence may be increasing. Missed injuries can lead to chronic pain, deformity and disability and this can be avoided by having a high index of suspicion. Subtle injuries are difficult to diagnose and special imaging or stress X-rays are useful in diagnosis. The classification proposed by Hardcastle et al. (J Bone Joint Surg 64-B (1982) 349) is used most commonly and the aim of treatment must be to obtain an anatomical reduction and stable fixation as soon as possible. Treatment after 6 weeks yields poor results and salvage arthrodesis is inferior to primary reduction and stabilisation. Reduction may be by closed or open methods and fixation by K wires, screws or bioabsorbable screws. Complications occur frequently and need to be detected and managed appropriately.

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History and introduction

Jacques Lisfranc de St. Martin (1790–1847) was a French gynaecologist and surgeon. He served in the Napoleonic army and described amputation through the tarsometatarsal (TMT) joint. During the Napoleonic era cavalry troops frequently sustained a Lisfranc dislocation when the foot became trapped in the stirrup. This often led to a profound vascular insult resulting in a Lisfranc amputation. The amputation was described by the French surgeon and it should be noted that he did not describe the fracture dislocation himself. Eponyms now associated with Lisfranc include Lisfranc amputation, Lisfranc dislocation, Lisfranc joints, Lisfranc ligament and Lisfranc fracture.

TMT injuries are rare and can be easily overlooked leading to long term pain and disability. Early diagnosis and prompt accurate reduction and stabilisation will minimise long-term disability. Controversies exist as to the best method of treatment for these injuries including open or closed reduction, use of screws or Kirshner wires, the timing of treatment and duration of immobilisation. However, in general, a consensus exists that precise anatomical reduction and stabilisation should be achieved as soon as is possible.

Lisfranc injuries account for 0.2% of all fractures and are more common in males. The incidence of Lisfranc injuries is low with 1 case per year in 55,000 fractures treated annually at the Boston City hospital. English found that only 24 or
0.2% of 11,000 patients treated at the Royal Infirmary in Edinburgh had fracture dislocations or multiple fractures involving the metatarsal bones. Vuori and Aro (1993)\(^{10}\) noted an increasing annual incidence of Lisfranc injuries from 7% during 1980–1984 to 12% from 1985 to 1989. That is a 70% increase over the two periods. This may represent a true increase with increasing numbers of high-energy vehicle accidents or better detection of these injuries. Between 20% to 39% of these injuries can be missed\(^{10,11}\) This is especially so in the patient with polytrauma who has concomitant head and chest trauma. The long bone fractures and major injuries are often given precedence with the foot injury given less attention. This combined with poor quality X-rays accounts for the missed or delay in diagnosis.

Anatomy

The TMT complex consist of the metatarsals, cuneiforms and cuboid bones with the stability provided by the osseous, capsule and ligamentous attachments.\(^{12}\)

Osseous stability

The bases of the metatarsals form a transverse arch, high medially and low laterally. In the frontal plane, the lateral aspect of the arch is 20 mm posterior to the medial side.\(^{13}\) The apex corresponds to the second metatarsal or middle cuneiform (Fig. 1). Additional bone stability is provided by the recessed nature of the second metatarsal between the medial and lateral cuneiform. The second metatarsal is often considered the "key-stone" as in a Roman arch and is important in maintaining the arch. The medial cuneiform protrudes 8 mm and the lateral cuneiform 4 mm relative to the second metatarsal, thus creating a cuneiform mortise, which receives its tenon, the 2nd metatarsal base. An interlocking mechanism also exists with the lateral cuneiform being recessed between the second and fourth metatarsal. As a result of the complex interlocking mechanism disruption of the TMT complex is often associated with a metatarsal fracture, usually the second.

Capsular stability

The articular capsule consists of a fibrous membrane lined by synovium. The joint capsule divides the TMT complex into columns and this has been proposed as a basis for the classification of these injuries\(^{14}\) The medial column includes the first TMT joint, the central column includes the second and third TMT joints and the lateral column includes the fourth and fifth TMT joints. The medial and lateral column capsule and synovial membrane do not communicate. The normal sagittal motion of the first TMT joint is 3.5 mm, the lateral column is more flexible with a sagittal motion of 13 mm and the central column the least flexible with only 0.6 mm motion. It is held virtually rigid in the recess.\(^{12}\)

Ligamentous stability

The ligaments of the Lisfranc complex are variable both in course, number and insertion. They are classified into dorsal, plantar and interosseous ligaments. Each has longitudinal and transverse elements. The longitudinal elements connect the TMT joint and the transverse the intermetatarsal and intercuneiform bones. There is no intermetatarsal ligament between the 1st and 2nd metatarsal.

The dorsal ligaments are short flat ribboned structures numbering 6–8. They are weaker than the plantar and interosseus ligaments; hence, dorsal disruptions or dislocations are more common.

The interosseous ligaments are strong and correspond to the first, second and third cuneiform-metatarsal space. The largest is the Lisfranc ligament, which is 8–10 mm long and 5–6 mm thick. It originates on the lateral side of the first medial cuneiform and inserts on the medial side of the base of the 2nd metatarsal. In 22% of cases the ligament is formed by two bands.\(^{12}\) Biomechanical studies of the Lisfranc ligament in cadavers has shown the strength of the ligament to be approximately 449N ± 58.\(^{15}\) No interosseous

Figure 1 Coronal CT scan at base of metatarsal. Second metatarsal forms the "apex" of the Roman arch. Note fractures of the base of 2nd and 3rd metatarsal.
ligaments exist in the fourth space. Following injury an avulsion of the Lisfranc ligament can occur and this is seen radiologically as a flake fragment in the first intermetatarsal space. This may be an avulsion from the metatarsal or the cuneiform.

The plantar cuneiform-metatarsal ligaments are well defined medially but variable laterally. They are variable in number. The first cuneiform metatarsal ligament is broad and there is no cuneiform-metatarsal ligament from the middle cuneiform to the second metatarsal. An oblique ligament connects the medial cuneiform to the base of the second and third metatarsal and is the strongest. In addition to the ligaments, soft tissue structures reinforce the plantar aspect making plantar dislocations unlikely. These include muscle, tendons such as the peroneus longus and also the plantar fascia.

Biomechanically the dorsal ligaments are weaker than the plantar and interosseus ligaments and as a result, in indirect injuries, the dorsal ligaments fail in tension before the plantar ligaments, hence dorsal dislocation being more common.

Classification

Early classifications of the Lisfranc joint were based on the mechanism of injury, which is often complex and variable. Direct force crushes the metatarsal plantarwards with secondary medial or lateral displacement. In indirect injuries rotational forces occur with the foot in a plantarflexed position. A dorsal dislocation results with additional displacement. These classifications help define the deforming force but do not provide information that would guide management.

Quénu and Küss' were the first to classify these fractures into a simple system based on the direction of metatarsal displacement. They classified the injuries into three groups, homolateral, isolated and divergent. It does not include every type of displacement and based on 119 TMT injuries was modified by Hardcastle (1982) into the current accepted classification (Fig. 2). Type A: Total injury: there is incongruity of the entire TMT joint. Displacement may be sagittal, coronal or both. Type B-Partial: there is partial incongruity. The displaced segment is in one plane. These injuries are further subdivided. Medial displacements affect the first metatarsal either in isolation or combined with displacement of second, third or fourth metatarsal. Lateral displacement affects the 2–5th metatarsal, not the first. Type C: Divergent: These can be partially or totally incongruent. The first metatarsal displaces medially and the lateral four, single or in combination, displace laterally. This classification allows treatment to be planned and is also useful for prognosis. Myerson has proposed a columnar classification based on the anatomical division of the TMT complex into medial, central and lateral columns. Although the classification is simple it has not yet been validated. A further classification was proposed by Nunley to include subtle injuries in athletes where low energy injury often leads to midfoot sprains. Nunley categorised these into three stages. Stage 1 injuries are undisplaced injuries of the TMT complex with pain, local tenderness and a positive bone scan with normal weight-bearing X-ray. Stages 2 and 3 are displaced injuries seen on X-ray. Treatment of stage 1 is with a plaster cast for 6 weeks initially and a further 4 weeks if tenderness persists. Stages 2 and 3 are treated as displaced Lisfranc injuries outlined below.

Mechanism of injury

During the Napoleonic era Lisfranc injuries were commonly sustained following a fall off a horse with the foot trapped in the stirrup. This mechanism is now rare and most injuries occur following road traffic accidents, a crush injuries e.g. industrial, following a fall or are sports related. Minor trauma such as a simple twist can also lead to a Lisfranc injury especially in elderly patients and athletes. The exact mechanism of the injury is not known because of the intricate nature of the TMT complex and the variable nature of the forces inflicted on it. Early studies showed that a violent force resulted in various injury patterns. Jefreys found in cadaveric experiments that pronation (eversion) of the hindfoot with the forefoot fixed resulted in a type A injury. Supination (inversion) of the hindfoot with the forefoot fixed resulted in a type B partial injury. A general consensus exists that the basic mechanism can be classified into direct and indirect injuries.

Direct injuries as a result of crushing are often associated with significant trauma to surrounding tissues and may be associated with an open injury, compartment syndrome or ischaemia. Gissane highlighted the fact that amputation may result if reduction is delayed in injuries where there is vascular compromise. The metatarsals are often displaced plantarwards (Fig. 3a and b) but Myerson showed that in his series 43% of Lisfranc injuries...
caused by crushing had dorsal displacement of the metatarsal. The position of the metatarsal depends on the point of forces applied to the foot during the crushing injury.

Indirect injuries occur as a result of longitudinal forces applied with both the foot and ankle in a plantarflexed position. The dorsal ligaments fail in tension and the TMT joint is displaced dorsally primarily and secondary displacement either medial or lateral can occur.\textsuperscript{21} Such injuries can occur from a fall in the “toe dancer” position (Fig. 4) or more commonly in road traffic accidents when the forefoot is forced against the bulkhead on impact. Indirect injuries are more common than direct injuries. Type C injuries are more difficult to explain and the exact mechanism for these has not been established.

**Associated injuries**

Fractures of the tarsal and metatarsal bones frequently occur in association with Lisfranc injuries. They are often associated with high-energy

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**Figure 2.** Classification of Lisfranc injuries. (Reproduced with permission and copyright\textsuperscript{©} of the British Editorial Society of Bone and Joint surgery. Hardcastle PH, Reschauer R, Schoffmann W. Injuries to the tarsometatarsal joint... J Bone Joint Surg. 1982, 64-B. 349–356.)
injuries and may involve the cuboid, calcaneus, talus and malleoli. Aitken and Poulson\textsuperscript{8} reported that fractures of the base of the second metatarsal and crush injuries of the cuboid were most frequently associated with Lisfranc injuries. Wilppula\textsuperscript{22} reported 18 out of 26 patients had associated fractures (69\%) of the foot. Myerson\textsuperscript{9} found 32\% of patients had an ipsilateral foot and ankle concomitant fracture. Metatarso-phalangeal dislocations can also occur and may occur in isolation to give rise to a single floating metatarsal.\textsuperscript{23–25} Direct crush injuries can result in significant soft tissue injury and may cause ischaemia or compartment syndrome. Prompt early reduction may prevent further vascular compromise and avoid the need for amputation.\textsuperscript{20} If compartment syndrome is suspected then the compartment pressures may be monitored and an urgent fasciotomy performed.

Clinical symptoms and signs

The symptoms and signs following a Lisfranc injury are variable. Subtle injuries with only mild tenderness and minimal swelling of the midfoot may occur in athletes or elderly. In patients with high-energy trauma significant pain, swelling and deformity occur. Open crush injuries are common and will require prompt debridement and stabilisation. Spontaneous reduction of the TMT joint can occur, masking the extent of injury and leading to a delay in diagnosis. Bruising on the plantar aspect may also be a clinical indicator of a Lisfranc injury.

Investigations

For all Lisfranc injuries standard AP, lateral and 30\(^\circ\) internal oblique views should be obtained both initially and after reduction. On the AP view the first and second TMT joints are visualised and in the oblique view the lateral 3–5th TMT joints seen. Normal consistent parameters have been established which can help with diagnosis (Table 1).\textsuperscript{26} On the lateral view the relationship of the medial cuneiform to the fifth metatarsal base can be used to identify significant injuries with flattening of the medial arch. The normal relationship with the medial cuneiform being higher than the fifth metatarsal is reversed.\textsuperscript{27} A high index of suspicion should be maintained as up to 39\% of injuries can be missed especially in subtle injuries and where the fracture dislocation has reduced spontaneously. In patients with polytrauma other injuries distract from the foot injury and this combined with poor quality X-rays often leads to a delay in diagnosis. If any doubt exists, then the other foot can be X-rayed for comparison and weight-bearing views obtained (Fig. 5).\textsuperscript{28} If pain and tenderness prevent
full weight bearing then this may be performed under regional ankle block or once pain and swelling have subsided. Avulsion fracture at the base of the first metatarsal or cuboid should also raise suspicion. The Fleck sign may be seen which represents an avulsion of the Lisfranc ligament (Fig. 6).

Subtle injuries in athletes and elderly may be difficult to diagnose. In these cases, stress views under regional or general anaesthetic may be performed with abduction and pronation stressing of the TMT joint\textsuperscript{18} with the hindfoot stabilised or compression and distraction of the second TMT joint.\textsuperscript{14} Any obvious instability is detected and the injured and non-injured side can be compared.

CT scanning is indicated if plain X-rays are normal and suspicion exists of a Lisfranc injury. Fractures of the base of the metatarsal and cuneiforms are easily identified and joint congruity assessed. Any soft tissue interposition can also be detected as well as small flake fragments. The disadvantage of CT scans are that they are static images and may not be as useful in pure ligamentous injuries which need dynamic imaging.\textsuperscript{14} In one cadaveric study CT scan detected all injuries with 1 mm and one third of all 2 mm displacements compared to none detected by plain X-ray.\textsuperscript{29} Although CT scans are sensitive, their role is limited for the evaluation of complex comminuted fractures where surgical treatment may be modified if severe comminution exists precluding internal fixation.

MRI has been used to identify subtle and pure ligamentous injuries to the TMT joint. Priedler\textsuperscript{30} was the first to show that MRI can accurately detect ligament injuries, fractures and displacement of the TMT joint. MRI also allowed the Lisfranc ligament to be visualised and any disruption detected (Fig. 7). The Lisfranc ligament is seen as a hypointense band-like structure between the medial cuneiform and the second metatarsal base. In a subsequent study Preidler\textsuperscript{31} showed the superiority of MRI scan compared to plain X-rays in 49 patients with hyperflexion injuries of the foot. Plain X-rays missed 50% of the TMT injuries.

### Principles of treatment

The major advance in the last decade has been the emphasis on early stable anatomical reduction and stabilisation of these injuries. In displaced

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**Table 1** Normal X-ray parameters used for identifying Lisfranc injury.

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<tr>
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<th>Description</th>
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<tr>
<td>1</td>
<td>The first metatarsal lines up medially and laterally with the medial cuneiform</td>
</tr>
<tr>
<td>2</td>
<td>The first intermetatarsal and intertarsal space have equal widths</td>
</tr>
<tr>
<td>3</td>
<td>Medial border of the 2nd metatarsal aligns itself with medial border of middle cuneiform</td>
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<tr>
<td>4</td>
<td>Lateral border of 3rd metatarsal aligns itself with lateral border of lateral cuneiform</td>
</tr>
<tr>
<td>5</td>
<td>The medial border of 4th metatarsal aligns itself with medial border of cuboid</td>
</tr>
<tr>
<td>6</td>
<td>Dorsal or plantar displacement on lateral views</td>
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fractures and dislocations non-operative management has a limited role. Only two studies have reported satisfactory results with non-anatomic reduction\(^8,32\) Brunet\(^32\) reviewed 33 patients after an average 15 years and found neither the initial fracture type, nor the type of treatment had any affect on outcome. Myerson\(^18\) advised that there is no place for closed reduction and plaster cast application as once the soft tissue swelling subsides redisplacement is very likely. In addition the strong plantar muscle and tendon tend to bowstring the TMT joint and maintain displacement. Of 15 patients undergoing this treatment no excellent results were achieved. The vast majority of evidence supports early anatomical reduction and stable fixation.\(^4-5,14,22,34\) Arntz\(^33\) concluded that there was a direct correlation between achieving an accurate reduction and a satisfactory clinical outcome. This was confirmed by Myerson\(^5\) who reviewed 60 patients after an average 4.2 years follow up and found a correlation between the quality of initial reduction and the outcome (Fig. 8). Although perfect anatomical alignment does not guarantee a good clinical outcome the outcome is more favourable.

Although most studies have shown that early anatomical reduction and stable fixation leads to the best outcome, no consensus exists on how to achieve this. Reduction may be by closed or open methods, fixation by K wires or screws and the duration of immobilisation is variable. An algorithm showing the principles of management is shown in Fig. 9.

Closed reduction and Kirschner-wire (K-wire) stabilisation

Closed reduction can be achieved with longitudinal traction, which may be aided by Chinese finger traps. Once reduction is achieved then the TMT joints should be stabilised. Hardcastle\(^4\) found the main reason for unsatisfactory results was redisplacement if the Lisfranc injury was not stabilised with a K-wire. He advised that Type A injury is treated with a K-wire across the first TMT joint and a second laterally into the fifth TMT joint. For type B injuries a single lateral K-wire for lateral segment injuries and two K-wires into the first TMT for medial injuries should be used. In type C injuries two medial and one lateral can be used. The K-wires are removed at 6–8 weeks. Some of the disadvantages with a K-wire include migration, breakage, infection and loss of reduction.\(^33\) In pure ligamentous injuries 6–8 weeks of immobilisation may not be sufficient for the ligaments to heal and prolonged use increases the risk of infection. However, studies have shown good outcomes with closed reduction and K-wire stabilisation. The main determinant of outcome appears to be early anatomical reduction and stabilisation.\(^4,14,34\) Post operatively the foot is protected in a below knee plaster cast with non-weight bearing for 6 weeks. The wires can then

![Figure 7 MRI scan showing Lisfranc ligament (arrowed).](image)
be removed at 6–8 weeks and an orthosis to support the medial arch given for 3–6 months.

**Open reduction and stabilisation**

Failure to reduce a Lisfranc injury may be due to a fracture fragment, soft tissue or tendon interposition such as the tibialis anterior tendon between the medial cuneiform and first metatarsal.\(^4\)\(^,\)\(^18\) The aim should be reduce the TMT joint anatomically. Any residual displacement of 2 mm or more between the medial and intermediate cuneiform, a talometatarsal angle greater than 15\(^\circ\) or any coronal displacement results in a poor outcome.\(^5\)

The surgical approach depends on the type of the fracture. A dorsal incision over the second metatarsal allows adequate exposure of the first and second TMT joint. The neurovascular bundle deep to extensor digitorum brevis is carefully protected. The second lateral incision should leave a sufficient bridge to prevent skin necrosis and is usually centred on the fourth metatarsal. The branches of the superficial peroneal nerve should be identified and protected to prevent damage and neuroma formation.

Several studies have shown that stabilisation using screws can avoid the complication of K-wires and maintain a stable reduction. Closed reduction and percutaneous use of cannulated screws has been described with good clinical results.
Primary stabilisation of the medial cuneiform to the base of the second metatarsal is first performed. The first TMT joint is stabilised next with a 3.5 or 4 mm cannulated screw, then the lateral TMT joints are reduced and stabilised. The lateral TMT joints often reduce spontaneously once the first and second are stabilised. Occasionally, the cuboid may require distraction and stabilisation if crushed. The lateral 3–5th TMT joints are normally stabilised with a K-wire. Partial weight bearing can be commenced immediately in a below knee cast and full weight bearing allowed at six weeks. The screws are removed at 4 months but occasionally can be left longer. There is no evidence that partial or fully threaded screws have any difference in the rate of osteoarthritis in the TMT joint. Damage to the TMT at the time of the initial injury probably determines the rate of osteoarthritis. In diabetic patients, who form a special subgroup, large 6.5 mm screws may be required if bone quality is poor. Screw breakages can occur and in one study this complication occurred in 25% of cases where screws were only removed for symptoms or signs. Thordarson reported on the use of polylactide (PLA) bioabsorbable screws with good clinical results. Fourteen patients with a Lisfranc injury underwent open reduction with stabilisation using PLA screws. No soft tissue reaction, osteolysis or loss of reduction was reported. The need for subsequent surgery to remove metalwork was avoided.

Cuboid crush injuries should be treated to restore the lateral column length with distraction, bone grafting and stabilisation either with a cervical H plate or K-wires. In severe compound injuries precluding internal fixation, stabilisation can be achieved with external fixators and definitive surgery performed once the soft tissue injury has healed and the swelling reduced.

Timing of surgery

The aim of treatment should be early anatomical reduction and stable fixation within 24 h. Early reduction reduces the risk of vascular compromise, skin problems and facilitates anatomical reduction. If significant swelling exists then surgery can be delayed until the swelling has reduced. Dislocation without a fracture may be treated up to three months after which salvage arthrodesis is advised. Hardcastle reported poor results if reduction was performed after 6 weeks and this may be due to joint incongruity and damage, and difficulty with reduction due to soft tissue interposition.
Complications

Early complications

The early complications include vascular injury, compartment syndrome, redislocation, complex regional pain syndrome and skin necrosis. Gissane reported 3 patients who underwent below knee amputation for vascular compromise and advised that reduction should not be delayed. Hardcastle reported 2 patients out of 22 with type A injuries who underwent amputation for ischaemia. Myerson reported a 13% amputation rate in patients with predominately high-energy injuries with polytrauma. Compartment syndrome might develop especially in crush injuries. The reported incidence is 4–7%. A high index of suspicion should be maintained and early fasciotomy performed. Redislocation can occur early especially if stabilisation has not been performed. However, late dislocation has been reported despite internal fixation for a minimum period of 4 months.

Late complications

Late complications include osteoarthritis of the TMT joints, deformity (pes planus, cavus or planovalgus), chronic pain, prominent exostoses, non-union and abnormal gait. As a result of the mechanism of injury and energy transferred osteoarthritis occurs in many patients despite adequate reduction. Myerson reported a 15% incidence of osteoarthritis in patients with good or excellent quality of reduction. The incidence is higher if reduction was non-anatomical and it may also be higher in pure ligamentous injuries. The presence of osteoarthritis radiologically does not correlate with the clinical outcome. Any salvage procedure for osteoarthritis should be delayed for at least 12 months as the symptoms or signs can improve for an average 1.3 years.

Outcome

In general, most studies have consistently shown that the clinical and functional outcome following Lisfranc injuries are better if early anatomical reduction and stable fixation is performed. Although anatomical reduction and fixation does not guarantee an excellent outcome the studies have shown that non-anatomical reduction leads to poor results. Stenström reviewed 40 patients at 5 years and found no patient with an excellent result if reduction was non-anatomical and half of these were on a full pension. In those patients with an anatomical reduction 50% had good or excellent result and only 25% of them were on a full pension. Following anatomical reduction Teng et al. found that after an average of 41 months the objective gait analysis was restored to normal but subjectively patients were less satisfied due to stiffness and discomfort.

Primary arthrodesis has been advocated by Granberry and Lipscomb and may be indicated if severe comminution of the TMT joint exists preventing stable reduction. Most studies do not support this and have found this not necessary.

Persisting pain and discomfort with or without deformity can be treated with functional foot orthoses initially. If this does not alleviate the symptoms then an arthrodesis is indicated. Identification of the painful joint may require further investigations with a bone scan, selective local anaesthetic injections and CT scanning. Arthrodesis for painful osteoarthritis of the TMT may be performed in-situ where there is minimal deformity or a realignment arthrodesis with or without bone grafting may be necessary. Johnson and Johnson used a dowel technique in 15 patients with an in situ technique. Good or excellent results were seen in 70% with only 2 non-unions. Sangeorzan reported 69% good or excellent results in 20 patients who underwent a realignment arthrodesis with structural iliac bone graft. Four of these patients returned to their preinjury occupation. On average 3 joints were fused. The results of salvage arthrodesis are not as good as primary anatomical reduction and stable fixation. Myerson showed no good or excellent results in those cases where an arthrodesis was performed.

Conclusion

Lisfranc injuries are relatively uncommon injuries but with increasing motor vehicle use their incidence may be increasing. Missed injuries can lead to chronic pain, deformity and disability and this can be avoided by having a high index of suspicion for these injuries. Subtle injuries are difficult to diagnose and special imaging or stress X-rays are useful in diagnosis. The classification proposed by Hardcastle et al. is used most commonly and the aim of treatment must be to obtain an anatomical reduction and stable fixation. Myerson showed no good or excellent results in those cases where an arthrodesis was performed.
K-wires, screws or bioabsorbable screws. Complications occur frequently and need to be observed and treated appropriately.

References