The diagnosis and treatment of injury to the tarsometatarsal joint complex
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Although the eponym ‘Lisfranc dislocation’ is still often used to describe injuries to the tarsometatarsal joints, the term is misleading. It probably originated from the time of Napoleon and relates to injury to the foot sustained in falling from a horse, accompanied by severe vascular damage which necessitated amputation, the only method of treatment used by Lisfranc, surgeon to the Emperor. Since then, the incidence of severe vascular complications associated with injuries to the tarsometatarsal joint has declined to the extent that the only circumstances under which circulatory compromise is treated is in the presence of a compartment syndrome. Injuries to the midfoot are best described as those affecting the tarsometatarsal joint complex (TMC) which includes all the bones and joints directly or indirectly involved in a tarsometatarsal fracture-dislocation, including the cuneiforms, cuboid, and navicular. Although high-energy injuries to the TMC occur commonly today after motor-vehicle, motorcycle, and industrial accidents, they may also be seen in association with minimal trauma from minor twisting injuries, particularly in athletes and the elderly.

The concepts of the treatment of injury to the TMC have changed markedly over the past decade. In 1986, Myerson et al highlighted the severe morbidity associated with these injuries and identified the factors associated with a poor outcome, particularly residual angulation of the metatarsals or diastasis of greater than 2 mm between the base of the first and second metatarsals. Failure to obtain an anatomical reduction is the most significant reason for a poor result. In these patients, the treatment had either been non-operative or, if surgery had been performed, Kirschner wires (K-wires) had been used for fixation. It was further recognised that premature removal of these K-wires resulted in subsequent diastasis or redislocation. Arntz, Veith and Hansen first popularised the use of screws in preference to K-wires and, since then, there have been a number of papers emphasising the need for anatomical reduction stabilised by rigid forms of internal fixation.

The aim of treatment should always be to obtain such a reduction and then to maximise the function of the foot. Unfortunately, the magnitude of this type of injury is often not appreciated because partial spontaneous reduction of the joint complex may mask the true extent of the injury. Even apparently minor injuries with subtle subluxation and diastasis of the articulation have marked morbidity if left untreated.

Functional anatomy of the tarsometatarsal joints

A review of the functional anatomy and diagnosis of this injury will promote a better understanding of the concepts of treatment.

The tarsometatarsal articulation consists of three functional units, previously referred to as columns. The medial column, formed by the base of the first metatarsal and the medial cuneiform, allows approximately 3.5 mm of dorsal plantar movement. The second metatarsal and the middle cuneiform with the third metatarsal and lateral cuneiform form the middle column. The second metatarsal is held rigidly between the bases of the first and third metatarsals; it has minimal sagittal movement, approximately 0.6 mm, and is dovetailed to articulate with these metatarsals and the surrounding cuneiforms. The lateral column is formed by the fourth and fifth metatarsals and the cuboid. It moves considerably more than does the medial or middle column in both the sagittal and horizontal planes, to 13 mm in the sagittal plane, as well as in pronation and supination.

This division of the joint into columns has important implications in treatment because the segmental patterns of injury which occur influence the approach to fixation. Although there are many classifications of injury to the TMC, including a comprehensive one proposed in 1986, the columnar classification gives a more utilitarian approach to the management of incongruity and instability. There is marked structural rigidity of the joint created by the wedge shape of the metatarsals and the corresponding cuneiforms, the dovetailing of the second metatarsal base and the strong interosseous ligaments located towards the plantar aspect of the metatarsals. The base of each metatarsal is connected by these ligaments, except for that of the

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first and second metatarsals where an extremely strong ligament, the ligament of Lisfranc, extends from the medial side of the base of the second metatarsal obliquely into the medial cuneiform. There are also secondary stabilisers including the plantar fascia, the intrinsic muscles, and the insertions of the peroneal, anterior tibial and posterior tibial tendons which reinforce the complex structure of the midfoot.

The aetiology of the injury

Fracture and dislocation may occur secondary to either direct or indirect forces. Those which occur secondary to a crushing injury produce a variety of patterns of dislocation with marked disruption of the skin and other soft tissues. These injuries are associated with compartment syndromes and an extended margin of damage to the tissue distal to the point of impact, referred to as the zone of injury.\textsuperscript{12-14} With indirect trauma, the forces produced are generally longitudinal and are applied to the foot with elements of torque, rotation and compression. The foot is usually plantar flexed at the time of impact, rupturing the weaker dorsal con-
to confirm or clarify the diagnosis of subtle injury. Stress radiographs may be of value in determining patterns of instability which may not otherwise be evident. These should be performed under appropriate anaesthesia with fluoroscopy. The foot is manipulated by a combined force of pronation and simultaneous abduction to detect any diastasis or angulation not noted previously (Fig. 1).

Treatment

There are very few indications for the non-operative management of displaced fractures or fracture-dislocations of the TMC. These predominantly ligamentous injuries are associated with marked articular instability, requiring immobilisation for four months to ensure adequate healing. Although a closed reduction and application of plaster may achieve a modest realignment, this form of immobilisation does not lead to an optimal outcome. The reduction obtained is lost when the soft-tissue swelling decreases, and repeat manipulation of the foot rarely maintains adequate position of these small joints. Dislocation is always associated with disruption of the dorsal and plantar capsule and ligaments, which predisposes to further displacement and angulation of the joint.

Particular attention should be given to fractures associated with crush injuries. Care of the soft tissues will determine the immediate success of treatment. Compartment pressures should be measured and fasciotomies performed if the pressure is greater than 40 mmHg. Ideally, surgery should be performed within the first few weeks after injury, unless a compartment syndrome is present, in which case fasciotomy is performed immediately on diagnosis. If a dislocation is not associated with a fracture, an operative reduction may still be obtained months after injury. I have successfully reduced a missed chronic dislocation one year after injury without resorting to arthrodesis. This is not ideal, however, because scarring, contracture of the joint and necrosis of cartilage may occur, preventing either an anatomical reduction or a successful outcome.

If the extent of the injury is not clear, the foot is manipulated under anaesthesia and the displacements noted fluoroscopically. This is important for determining the presence of subtle diastasis between the medial and middle columns. After manipulation this column can also be stabilised if further instability is noted. The aim of treatment should be a stable anatomical reduction, which can be accomplished only by rigid internal fixation. It has to be decided whether the reduction will be best obtained through open or closed methods, and whether screws or K-wires are to be used for fixation. Whenever possible, I attempt a closed reduction and percutaneous screw fixation. This is generally easily accomplished, regardless of the magnitude of the dislocation and deformity, by a manipulative manoeuvre which involves longitudinal distal traction of the forefoot. The sequence of reduction is then checked fluoroscopically, noting any diastasis or step-off of the articulation (Fig. 4). Closed reduction is facilitated by a large bone reduction clamp which reduces the second metatarsal into the mortise (Fig. 5). If any diastasis is still noted, the clamp may be adjusted or an open reduction may be performed. Malreduction is usually due to interposition of a fracture fragment or soft tissue at the base of the second metatarsal, preventing anatomical apposition between the medial and middle columns. If an open reduction is performed, it is not always necessary to remove the small fragment of bone because it can be pushed plantar-
wards, facilitating reduction. There is an advantage in preserving the fragment in terms of primary bone healing and enhanced stability. Occasionally, soft tissue may be interposed and dislocation of the tendon of tibialis anterior between the middle and medial columns into the medial tarsal metatarsal joint has been reported.\textsuperscript{22,23}

Once the base of the second metatarsal has been reduced anatomically, the first metatarsal is positioned correctly on the medial cuneiform. Generally, there is abduction of the first metatarsal, the hallux is grasped, and the base of the first metatarsal is pushed laterally (Fig. 6). While holding the hallux in varus, a guide pin or K-wire is inserted to stabilise the medial column, and the position is checked fluoroscopically. If full reduction has been obtained, the second metatarsal is then stabilised. Two small puncture incisions are made, one over the dorsum of the second metatarsal and one over the medial surface of the medial cuneiform. A partially threaded screw is inserted obliquely from the medial cuneiform into the base of the second metatarsal, which can be easily accomplished using a cannulated screw under fluoroscopy. This manoeuvre often realigns the entire articulation because the second metatarsal pulls the third and fourth metatarsals with it. If the lateral column is unstable, it is secured percutaneously using either 1.6 mm K-wires or a screw inserted into the cuboid. I prefer to use screws because they give the most rigid form of internal fixation and facilitate earlier rehabilitation of the foot. The rigid stability provided far outweighs the minor potential for the delayed onset of degenerative arthritis. Because these are primarily ligamentous injuries, the screws are left in place for a minimum of four months. Infection is always a possibility when pins have been introduced percutaneously, and the reduction will be compromised if they have to be removed prematurely (Fig. 7). Therefore, if pins are used, they should be buried subcutaneously for later retrieval. A combination of screws and K-
wires may be used to secure fragments which are too small for screw fixation.

Most dislocations can be treated in this manner, and open reduction is performed only if the anatomy of the articulation cannot be re-established. The surgical approach selected depends on the pattern of fracture or dislocation. Generally, a dorsal longitudinal incision centered over the second and fourth metatarsals gives adequate exposure of the medial and middle columns (Fig. 8). This is the same as the medial incision used to perform a fasciotomy in conjunction with a compartment syndrome. The incision is lateral to the neurovascular bundle, which is located deep to the tendon of extensor hallucis brevis. If the adjacent lateral metatarsals do not reduce, an incision is made between the fourth and fifth metatarsals. This must be slightly more lateral in the presence of a crush-type fracture of the cuboid (Fig. 9). These two incisions are all that are needed, because the remaining pins or screws are inserted percutaneously across the joints requiring stabilisation. I use 3.5 mm cortical screws introduced without compression. If a dislocation of the middle column is present, it is preferable to use a larger, partially threaded 4.5 mm screw to reduce and hold the second metatarsal in its mortise. The latter screw is introduced from the medial cuneiform into the second metatarsal. The entry point for the screw into the second metatarsal should...
be approximately 16 to 20 mm distal to the joint and the screw should be introduced at an angle of 30° to the metatarsal shaft. Countersinking the screw head, which is essential to prevent fracture of the proximal metatarsal, is initiated with a 4 mm burr before inserting the countersink tool.

If a fracture of the cuboid is present, the length of the bone must be re-established. This has been referred to as a ‘nutcracker’ fracture, and is due to the abduction force on the lateral column during injury. The length of the lateral column is established indirectly either with a small distractor or external fixator, or using a construct of K-wires and a lamina spreader (Fig. 9). This manoeuvre is often necessary before the reduction of the medial or middle column. Once the correct length and alignment are established, the lateral column is temporarily secured by K-wires. To restore the length of the cuboid, a bone graft is necessary; it may be harvested from the ipsilateral calcaneus or, if a tricortical graft is required, from the distal tibia, iliac crest, or allograft. If the cuboid is crushed centrally with maintenance of the subchondral surfaces, a small plate is ideal for maintaining the length of the bone; I use a five-hole H-plate. If there is insufficient bone on one or both sides of the joint to support the plate, it must then span one or both sides of the cuboid into the fifth metatarsal or calcaneum (Fig. 9c).

**Postoperative management**

Persistent postoperative swelling is a considerable problem in rehabilitation after these injuries. It can be minimised by an early regime of exercises when fixation is accomplished with screws. Alternatively, an intermittent compression foot pump (AV Impulse System; Kendal, Mansfield, Massachusetts) may be used to reduce the swelling.

Patients are not allowed to bear weight for two weeks and the limb is immobilised in a below-knee posterior plaster splint. For eight weeks thereafter, toe-touch weight-bearing in a removable articulated walking boot is allowed. Early movement of the foot is ideal and is enhanced by rigid skeletal fixation. These primarily ligamentous injuries take four to five months to heal fully, and rehabilitation with physiotherapy is encouraged. All internal fixation should be removed before full activities are begun, usually after four months.

**Post-traumatic arthritis**

Perhaps the most common problem after injuries to the TMC is the development of post-traumatic arthritis. Although high-energy injuries often produce abraded or crushed articular surfaces, which may develop arthritis despite appropriate reduction, most studies have found that the subsequent development of degenerative changes is markedly increased if the extent of the injury has initially been unrecognised, if the injury has been only partially treated, or if the anatomy was not restored.

In an earlier retrospective study, Komenda et al evaluated 32 patients who had had tarsometatarsal arthrodesis for intractable pain after trauma of the midfoot and found that in most the extent of the injury had not been appreciated and the reduction was inadequate.

There may be some difficulty in identifying the painful joints, but the middle column, the joints of which have least movement, and to a less extent the medial column, are the most commonly involved. It is particularly important to recognise the lack of association between the extent of arthritis and symptoms. For example, the second metatarsocuneiform joint, which has the least movement of the midfoot, has been noted to be the most painful.

Conversely, many patients with radiological evidence of arthritis of the joints of the lateral column do not experience pain at this site, perhaps because the lateral column is the most mobile in both the sagittal and horizontal planes.

Post-traumatic arthritis may be treated initially by non-operative means including non-steroidal anti-inflammatory drugs, moulded orthotic insoles, a stiff-soled shoe with a rocker-bottom, and more rigid immobilisation by a polypropylene ankle-foot orthosis. If these methods fail to relieve symptoms to an acceptable level, arthrodesis of the painful tarsometatarsal joints is the treatment of choice. - The decision as to the extent of the arthrodesis should be based on the location of pain and the radiological appearance of the joints. I have not in the past relied on other methods of imaging or selective injections to determine the joints to be fused.

There are two means of obtaining fusion. In the presence of minimal deformity, an in situ arthrodesis can be performed with no attempt at realignment of the TMC, but if deformity of the forefoot and/or midfoot is present, correction of both the sagittal and transverse planes must be obtained. Additional procedures such as arthrodesis of the naviculocuneiform and calcaneocuboid joints, osteotomy of the calcaneus, neurectomy and nerve transposition for intractable dorsal neuritis and clawtoe procedures for forefoot deformity should be undertaken if required.

Arthrodesis in situ is indicated for minimal deformity with arthritis limited to the middle and/or medial column; the middle column is most often involved. Minimal reduction is required with this technique, the position of articulation is temporarily secured with cannulated guide pins, and radiographs are obtained. The screw size is selected according to the size of the metatarsal; I use either 4.0 or 4.5 mm cannulated screws.

It has been demonstrated that realignment of the forefoot is preferable to an arthrodesis in situ for patients with residual displacement and deformity after injury to the TMC. Any malalignment must be appreciated in both the transverse and sagittal planes because, unless corrected, dorsal angulation of the medial column can be debilitating. Some patients have a flatfoot deformity associated with forefoot abduction and lateral translation with...
dorsiflexion of the metatarsals. The medial soft tissues, including the abductor hallucis and posterior tibial tendon, as well as the supportive ligaments, are often attenuated, and the lateral soft tissues are contracted. In order to restore the anatomy of the forefoot, the medial base of the first metatarsal is first corrected by aligning it with the medial edge of the medial cuneiform. Then the alignment of the medial base of the second metatarsal with the medial edge of the middle cuneiform in the transverse plane is restored, as is the long axis of the talus with the long axis of the first metatarsal in both the sagittal and transverse planes (Fig. 10).\textsuperscript{34,37} Realignment is performed in a stepwise fashion, commencing medially with correction of the position of the first metatarsal, which is temporarily secured by the cannulated guide pin(s). The second metatarsal is then reduced by placing a large bone reduction clamp obliquely between the base of the second metatarsal and the medial cuneiform to close the gap. The middle column typically moves together, and the third metatarsal will follow with this reduction of the second. Both the second and the third metatarsals are secured by the cannulated guide pins, by first inserting a pin from the medial cuneiform distally towards the base of the second metatarsal. Anteroposterior and lateral radiographs are obtained to confirm the corrected alignment. If there is marked deformity, the lateral joints are mobilised by resection of scar tissue, realigned and secured by either K-wires or screw fixation. This fixation of the lateral column is temporary and should be removed once weight-bearing is started at approximately eight weeks after operation. Arthrodesis of the lateral column is rarely required since this articulation is generally asymptomatic and should not be performed unless absolutely necessary because of the resultant additional stiffness of the foot. After operation, the patient is placed in a bulky compression dressing, which is changed to a cast at two weeks. Weight-bearing is begun at approximately eight weeks, in a below-knee walking cast or a commercially available walking boot, which may be used for an additional four to eight weeks, depending on the healing of the arthrodesis.

After arthrodesis of the TMC, most patients are quite satisfied with their level of function and activity. If non-operative measures fail to relieve symptoms to an acceptable level, arthrodesis of the painful tarsometatarsal joints is the treatment of choice.\textsuperscript{31,34,35}

References

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