Tarsometatarsal Joint Complex and Midtarsal Injuries

Tarzometatarzální kloubní komplex a jeho poranění

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SUMMARY

In this article the following areas will be reviewed; the anatomy of the midfoot; mechanisms of injury and current classification systems; diagnosis; treatment options and the evidence for current practice; areas of treatment uncertainty and recommended guidelines for management.

INTRODUCTION

The tarsometatarsal joint complex (TMJC) divides the midfoot from the forefoot and includes the joints between the metatarsals and cuneiforms or cuboid as well as the intercuneiform and naviculocuneiform joints (36). In addition to the TMJC the midtarsal joint, also known as Chopart's joint, is a complex articulation with the hindfoot that includes the talonavicular and calcaneocuboid joints. Injuries can range from simple non-displaced fractures and sprains to markedly displaced fractures and dislocations. As a result of the broad spectrum of injury to both the TMJC and midtarsal joint, they continue not only to be a challenge to diagnose but also to treat. Injuries to the midfoot can be subtle, and up to 40% of tarsometatarsal injuries are missed on initial presentation, especially in the multiply injured patient (7, 18, 23, 57).

The incidence of midfoot injuries is relatively uncommon but appears to be increasing particularly in certain sports (4, 20,28). Midfoot injuries sustained in athletes are different to those that occur due to high energy trauma. As a result, a high index of suspicion is needed to recognize and accurately diagnose these injuries in order to avoid delayed presentation and its associated problems of deformity, disability and chronic pain (11, 18, 23, 53).

In this article the following areas will be reviewed; the anatomy of the midfoot; mechanisms of injury and current classification systems; diagnosis; treatment options and the evidence for current practice; areas of treatment uncertainty and recommended guidelines for management.

ANATOMY

The TMJC and midtarsal joint stability is dependent primarily upon osseous, ligamentous and capsular attachments. Secondary stabilisers of the midfoot include the plantar fascia, peroneus longus and the intrinsic muscles. 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 20mm posterior to the medial side (14). The second metatarsal is often considered a 'key-stone' as in Roman arch due to the recessed nature of the intermediate cuneiform. The medial cuneiform protrudes 8mm and the lateral cuneiform 4mm with respect to the second metatarsal. In addition, a second interlocking configuration exists between the lateral cuneiform and the bases of the second and fourth metatarsal bases. This provides a great deal of inherent stability to the TMJC.

The TMJC has been described in term of three columns (9). The medial column includes the first tarsometatarsal (TMT) joint, the central column includes the second and third TMT joints as well as articulations between the middle and lateral cuneiforms 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 3.5mm, the lateral column is more flexible with a sagittal motion of 13mm and the central column the least flexible with only 0.6mm motion. It is held virtually rigid in the recess (38). Most injuries involve the central column despite this rigidity conferred by both osseous and ligamentous stabilizers.

The ligaments of the TMJC are classified as dorsal, plantar and interosseous, each having longitudinal, oblique and transverse elements (14). The longitudinal and oblique fibres connect the cuneiforms and cuboid to the metatarsals, and the transverse ligaments connect the metatarsal bases. The dorsal ligaments are weaker than the plantar and interosseous ligaments, hence why dorsal dislocations are more common. The Lisfranc ligament runs obliquely from the base of the second metatarsal to the medial cuneiform and no ligament connects the base of the first to second metatarsal. In 22% of cases the ligament is formed by two bands. Biomechanical studies of the Lisfranc ligament in cadavers has shown the strength of the ligament to be approximately 449N+/-58 (48).

The midtarsal (Chopart) joint is named after Francois Chopart (1743–1795), who described the use of the talonavicular and calcaneocuboid articulations as a practical level for amputation. The midtarsal joint lies in a plane transverse to the medial and lateral longitudinal arches of the foot and allows the forefoot to move with respect to the hind foot on heel strike producing a flexible foot that can adapt to an uneven surface (when the hindfoot is everted, the two Chopart joints are parallel, allowing flexibility). At the toe-off phase of the gait cycle, the midtarsal joint is locked (when the hindfoot is inverted, the joints come out of their parallel configuration, stiffening the joints) producing a rigid platform for push off. The motion of these joints along with the subtalar joint are dependent on each other with the talonavicular joint being the most important to their overall motion. Simulated arthrodesis of the talonavicular joint has shown that it has the greatest range of motion and essentially eliminated motion of the other joints of the subtalar complex (6).

The talonavicular joint is stabilized through the static ligamentous structures as well as dynamic contributions from the tibialis posterior and intrinsic and extrinsic foot flexors. The spring ligament complex extends from the sustentaculum tali of the calcaneus to the plantar and medial aspects of the navicular and has been shown to have two portions (superomedial calcaneonavicular and inferior calcaneonavicular ligaments) (12). Lateral ligamentous support is provided by the medial limb of the bifurcate ligament, the lateral calcaneonavicular ligament. This originates from the anterior process of the calcaneus superiorly in the sinus tarsi and extends to the superior and lateral portion of the navicular. Dorsally, the talonavicular joint capsule is a thick structure that is defined as the talonavicular ligament. This occupies the space between the superomedial calcaneonavicular and the lateral calcaneonavicular ligament.

The navicular articulates distally via three facets with the medial, intermediate and lateral cuneiforms and has a shared capsule. On occasion a fourth articular facet is present between the navicular and the cuboid. There is very little motion at this articulation, however this is in contrast with its proximal articulation with the talus, which has been previously mentioned. The proximal and distal portions of the navicular are covered by articular cartilage and the blood supply enters both medially and laterally (branches of tibialis posterior and dorsalis pedis) (55). The central third portion is therefore relatively avascular and susceptible to stress fractures as a result of shear stress (51).

The calcaneocuboid joint is a saddle-shaped joint between the anterior process of the calcaneus and the proximal pole of the cuboid. An osseous projection at the inferomedial corner of the cuboid, the beak, articulates in the coronoid fossa of the calcaneus and adds to joint stability with the foot in inversion (44). The calcaneocuboid joint is supported plantarly by the inferior calcaneocuboid ligament. This extends from the inferior surface of the calcaneus to the inferior surface of the cuboid and has a superficial and a stronger deep portion that helps prevent dorsal subluxation. The superior portion of the joint is bounded medially by the medial calcaneocuboid ligament, which is the same as the lateral limb of the bifurcate ligament. The dorsolateral calcaneocuboid ligament originates on the anterior process of the calcaneus and extends from the articular surface of the calcaneus over the dorsum of the cuboid as the joint capsule (44).

The cuboid also articulates with the fourth and fifth metatarsals distally. Dorsal ligaments between the cuboid and calcaneus, lateral cuneiform, navicular and metatarsals contribute to its dorsal soft tissue envelope. A tuberosity on the plantar surface is present where the plantar ligament attaches and is integral in maintaining the lateral longitudinal arch of the foot. The major blood supply to the cuboid arises from the anterior tibial artery (the transverse pedicle branch arises from the proximal lateral tarsal artery) (19). Restoration of the anatomical structure of both the navicular and cuboid are important in maintaining the relative lengths of the medial and lateral columns of the foot respectively.

MECHANISMS OF INJURY

Jacques Lisfranc de St. Martin (1790–1847) was a surgeon during the Napoleonic era and Lisfranc injuries were commonly sustained following a fall off a horse with the foot trapped in the stirrup. He however, actually described a fast method of forefoot amputation via the Lisfranc joint.

Currently there are broadly two categories of injury to the TMJC, which can be classed as high or low energy or as direct or indirect injuries. High energy injuries are a result of motor vehicle collisions, falls from a height or a crushing injury (20). However, more recently low energy injuries have become more prevalent predominantly due to twisting injuries in athletes especially football (34, 37). Athletic injuries to the TMJC can be divided broadly into plantar flexion injuries and abduction injuries, although this is an oversimplification since there are probably varying patterns of each force. Plantar flexion injuries occur when an axial force is applied along the longitudinal axis of a foot that is in slight equinus with the metatarsals firmly planted on the ground distally, resulting in failure under tension dorsally (34, 47). Abduction injuries occur when the forefoot is forcefully abducted with the hindfoot fixed. The base of the second metatarsal dislocates and the remaining metatarsals dislocate in a lateral direction if the abduction force is great enough. This injury pattern is often seen in sporting activity where the foot is restrained such as equestrian sport and windsurfing (8).

Due to the complexity of the TMJC the exact mechanism of injury is often not known and this is probably more applicable to the high energy injuries where there a multiple deforming forces present (1, 20).

Navicular fractures are often the result of high-energy crushing or axial-load mechanisms, frequently with an abduction and flexion component (16). Cuboid fractures rarely present as an isolated injury and generally are caused by lower-energy mechanisms of injury. High energy injuries result from a global shortening of the midfoot through both the medial and lateral columns or as a result of a severe abduction force to the forefoot. This force produces a severely comminuted fracture caused by the cuboid being crushed between the fourth and fifth metatarsal bases and the anterior process of the calcaneus, hence the term ‘nutcracker fracture’ (22). The foot usually is in a position of plantar flexion and/or abduction (29). Alternatively, plantar flexion and abduction of the forefoot can impact the dorsolateral aspect of the articular facets of the fourth and fifth metatarsals into the cuboid. This injury may not necessarily result in shortening of the lateral column but can cause arthrosis. Weber and Locher (56) reported the largest series of cuboid fractures and observed this pattern in 11 of 12 patients. Five of the 12 patients had an additional crush component that resulted in shortening of the lateral column. A distraction force across the lateral aspect of the midfoot can result in avulsion type fractures that tend to be more common but result in fewer long-term problems than the compressive type injury of the cuboid.

CLASSIFICATIONS

Tarsometatarsal joint complex

Numerous classification systems exist for injuries to the TMJC. In 1909, Quénu and Küss described the first classification system dividing injuries into homolateral, isolated and divergent (41). Hardcastle in 1982 modified the Quénu and Küss classification based on 119 injuries to the TMJC. 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 modified this classification system after reviewing seventy-six fracture-dislocations of the TMJC. Type-B injuries were divided into medial dislocations (type B1) and lateral dislocations (type B2). Type-C injuries were divided into those with partial incongruity (type C1) and those with total incongruity (type C2) (36). However, this classification system is not validated at present but can also be useful in planning treatment.

Nunley and Vertullo reported on the management of midfoot sprains in fifteen athletes and created a new classification system to address subtle tarsometatarsal injuries with minimal or no displacement seen on weight-bearing radiographs (37). These injuries were categorised into three stages. Stage 1 injuries are undisplaced (<2mm of diastasis between the first and second metatarsals) injuries of the TMJC with pain, local tenderness and a positive bone scan with normal weight-bearing X-ray. Stage 2 injuries (2 to 5 mm of diastasis between the first and second metatarsals evident on AP radiograph but no arch collapse on lateral radiograph). Stage 3 injuries are displaced injuries seen as loss of arch height, defined by a decreased distance between the fifth metatarsal and the medial cuneiform on lateral weight-bearing radiographs. This classification system is reliant on the patient being able to fully weight bear in order to determine the diagnosis.

Navicular fractures

The navicular plays a major role in weight bearing during ambulation as a result of its strategic location in the medial longitudinal arch of the foot. Because of its position in the uppermost portion of the arch, it acts as the keystone for vertical stress on the arch. Therefore, reduction of navicular fractures is essential to prevent deformity and subsequent disability. DeLee has broadly classified navicular fractures into four groups: Type 1: avulsion fractures of the dorsal lip, Type 2: fractures of the tuberosity, Type 3: displaced and non-displaced fractures of the body, and Type 4: stress fractures (13).

Sangeorzan et al. (45) devised a classification system for displaced intra-articular fractures of the navicular body based on the direction of the fracture line, the pattern of disruption of the surrounding joints, and the direction of displacement of the foot. In a type 1 fracture, the primary fracture line is in the coronal plane (producing dorsal and plantar fracture fragments), and there is no angulation of the forefoot. In a type 2 fracture, the primary fracture line is dorso-lateral to plantar-medial across the body of the navicular. The major fragment is dorso-medial and is displaced medially along with the forefoot. The calcaneonavicular joint is not disrupted. In a type 3 fracture, there is a comminuted fracture in the sagittal plane of the body of the navicular. The medial border of the foot is disrupted at the cuneiform-navicular joint. The forefoot is laterally displaced.

DIAGNOSIS

The clinical symptoms and signs of midfoot injuries can vary and be subtle especially following spontaneous reduction of dislocations preventing early diagnosis. This can often be the case in athletic injuries and in the elderly where the injury mechanism is not particularly of high energy. Plantar ecchymosis (Fig. 1) localized to the midfoot is a useful sign and should raise suspicion of a significant midfoot injury in addition to marked swelling more in keeping with a high energy injury (43). A 'pop' may be felt especially in athletic injuries (23).

For all midfoot injuries standard AP, lateral and 30^0 internal oblique radiographs should be obtained. On the AP view the first and second TMT joints are visualised and in the oblique view the lateral 3^{rd}-5^{th} TMT joints are seen. Table 1 illustrates some of the normal radiological parameters of the midfoot (49). On the lateral radiograph the medial cuneiform should be higher than the base of the 5^{th} metatarsal and this is reversed in the case of a Lisfranc injury (Fig. 2) (18). If doubt exists regarding the diagnosis contralateral foot views can be obtained for comparison or weight bearing radiographs. If patients have significant pain a true weight bearing radiograph may be difficult to obtain. The "fleck" sign (Fig. 3) at the base of the second meta-

Tab. 1. Normal radiographic parameters of midfoot

1. Medial border of the 2nd metatarsal aligns with medial border of middle cuneiform
2. The medial border of 4th metatarsal aligns itself with medial border of cuboid
3. Dorsal or plantar displacement on lateral views – relationship between medial cuneiform and 5th metatarsal base
4. The first intermetatarsal and intertarsal space have equal widths
5. The first metatarsal lines up medially and laterally with the medial cuneiform
6. Lateral border of 3rd metatarsal aligns itself with lateral border of lateral cuneiform

Fig. 1. Plantar ecchymosis localized to the midfoot.

Fig. 2. Lateral radiograph illustrating the reversal of the relationship between the base of the 5^{th} metatarsal and medial cuneiform. The medial cuneiform is more inferior to the base of the 5^{th} metatarsal.

Fig. 3. The "fleck" sign illustrating an avulsion injury to the Lisfranc ligament.

tarsal or medial border of the medial cuneiform should also raise suspicion of an avulsion injury of the Lisfranc ligament (36).

If plain radiographs do not reveal an obvious injury and suspicion still exists then CT, MRI scanning and examination under anaesthesia are useful further investigations. Examination under anaesthesia and stressing the midfoot with an abduction and pronation stress test may reveal instability (Fig 4) (11, 33). There can be variation between the instability in the medial column and that in the middle column, and the instability can extend between the cuneiforms. This is not well demonstrated with the pronation abduction stress test and a more useful test is squeezing between the medial and middle columns to demonstrate evidence of instability radiographically (10).

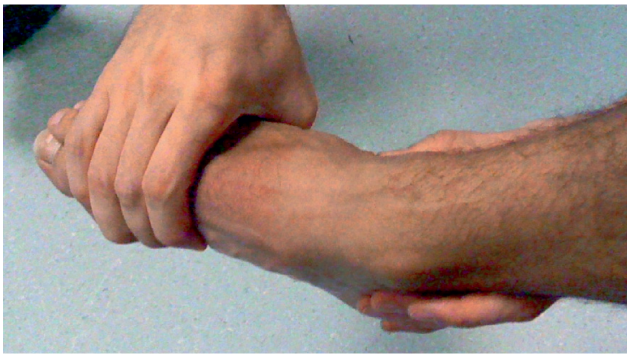

Fig. 4. The pronation abduction stress test.

CT scanning is a sensitive test to diagnose midfoot injuries and is particularly useful if severe comminution exists in order to determine the suitability of fractures to be treated with internal fixation. Cadaveric work has shown CT scanning is more sensitive than radiography for detecting the minor amounts of Lisfranc displacement. None of the 1mm and two thirds of the 2 mm dorsolateral Lisfranc dislocations could be visualized on routine radiographs; they could all be noted on CT scans (26). However, one has to remember CT scanning is a static imaging modality and often midfoot injuries are dynamic in nature (9).

MRI is useful in determining ligamentous injuries to the midfoot in the absence of fractures and has been shown to be superior to plain radiography (39, 40). The appearance of a normal ligament on MRI has been shown to be suggestive of a stable midfoot, and documentation of its integrity may obviate the need for a manual stress radiographic evaluation under anaesthesia for a patient with equivocal clinical and radiographic examinations (42).

TREATMENT OPTIONS AND EVIDENCE FOR CURRENT PRACTICE

Tarsometatarsal joint complex injuries

The main aim of treatment of TMJC injuries is early stable anatomical reduction. There is however a significant lack of Level I and II evidence to support treatment algorithms currently in place for injuries to the TMJC.

Non-operative treatment

The role of non-operative treatment of these injuries has not been clearly defined. Residual displacement of as little as 2 mm significantly decreases the total contact area of the articular cartilage and surgery is probably beneficial for even small degrees of displacement (15, 36). The degree of residual displacement tends to predict outcome in these injuries (4, 11, 20, 32). Myerson et al. reviewed 60 patients after an average 4.2 years follow up (Level IV evidence) and found a correlation between the quality of initial reduction and the outcome (36). Although perfect anatomical alignment does not guarantee a good clinical result, the outcome is more favourable. However, there are 2 studies (Level IV evidence) in the literature that suggest satisfactory results can be achieved with non-anatomical reduction(1, 7).

Minimally displaced stable injuries in athletes may be treated successfully non-operatively (11). A retrospective review of 15 patients by Faciszewski et al. (Level IV evidence) demonstrated residual displacement as much as 2-5 mm between the 1st and 2nd metatarsals was not associated with a worse outcome but preservation of the longitudinal arch was necessary for a good outcome (18). Nuney and Vertullo (Level IV evidence) based on their classification scheme recommend non-operative treatment for stage 1 injuries. They recommend non-weight bearing for 6 weeks in a cast and stage 2 and 3 injuries require anatomic reduction and stabilization (37). Myerson et al. recommends stable injuries confirmed on weight bearing or stress radiographs can be treated non-operatively in a boot as long as the reduction is maintained after 2 weeks (35). Weight bearing is permitted as tolerated at that stage with the use of an arch support until there is no pain on pronation abduction stress testing. Even with this treatment regimen the time to return to sport can be as long as 9 months following the injury.

Surgical treatment

Based on current evidence surgical treatment of TMJC injuries should be performed in unstable displaced fracture/dislocations and unstable purely ligamentous injuries. Some of the pertinent evidence is presented here but some of the following questions regarding surgical treatment need still need to be answered:

1. Timing of surgical intervention and how late can fixation be performed after injury?
2. Open or closed reduction?
3. Method of fixation?
4. What is the role of primary arthrodesis?
5.Post-operative regimen?
6. Necessity and timing of hardware removal?

Timing of surgery

The timing of surgery should be performed as soon as the soft tissue envelope allows is a good rule to follow but early reduction reduces the risk of vascular compromise, skin problems and facilitates anatomical reduction. Dislocation without a fracture may be treated up to three months after which salvage arthrodesis is advised (52). Hardcastle et al. showed that if reduction was performed after 6 weeks then a worse outcome was achieved (Level IV evidence) (20). Late treatment with arthrodesis has been described with successful results. Komenda et al. performed a retrospective analysis of 32 patients who underwent arthrodesis at a mean of 35 months following injury and the mean pre-operative AOFAS score was 44 compared to 78 post-operatively (Level IV evidence) (23). Sangeorzan et al. retrospectively reviewed 16 patients who had undergone arthrodesis as a salvage procedure and found good to excellent results in 11 (69%) of patients and fair or poor in 5 patients (46). Accurate reduction and early treatment had a significant effect on outcome.

Open versus closed reduction

The goal of reduction is to achieve an anatomic reduction and whether this is achieved via open or closed means is probably dependent on a number of factors including the timing of the surgery, the presence of fracture fragments or soft tissue interposition (including tibialis anterior (TA) tendon) preventing an anatomic reduction (20, 32). Closed reduction can be achieved with longitudinal traction on forefoot and medial displacement with pressure over the midfoot but it is very difficult to ensure anatomic reduction of the TMJC especially in extensive injuries where there is associated intercuneiform instability and open reduction is recommended.

K wire fixation

The use of K wire fixation with closed reduction has been described with good outcomes and the main determinant of outcome appears to be early anatomical reduction and stabilization (9, 20, 31). The concern with the use of K wire fixation is that for the period of time fixation needs to remain *in-situ* they can loosen and become infected. Arntz and Hansen emphasized the importance of screw fixation compared to K wire fixation due to the afore mentioned complications (Level IV evidence) (5). The medial and middle columns are rigid and the lateral column more mobile. Cadaveric work has shown that screw fixation is more rigid on the medial side of the foot compared to K wires but not statistically different on the lateral side (25).

Open reduction and internal fixation (screw +/- K wire fixation or plate fixation)

Mulier et al. published a series of 28 patients in a retrospective cohort study (Level III evidence), with severe, acute Lisfranc dislocations, requiring operative intervention, who were treated between 1989 and 1992 in a level one Trauma Centre (30). The Baltimore painful foot score was greater in the open reduction and internal fixation group compared to the arthrodesis group. Stiffness, loss of metatarsal arch and sympathetic dystrophy occurred more in the open reduction and internal fixation group. Different treatment protocols were used by the two senior staff surgeons and the conclusion was that primary complete arthrodesis should be reserved as a salvage procedure. Myerson *et al.* have stated that in athletes the treatment of choice for a TMJC injury requiring operative intervention should be anatomic internal fixation and not primary arthrodesis (35).

Kuo et al. performed a retrospective study of open reduction and internal fixation of Lisfranc injuries with screw fixation (Level IV evidence) (24). Forty eight patients were followed for an average of 52 months. Twelve patients developed secondary degenerative changes and 6 required an arthrodesis. Pure ligamentous injuries tended to have a poorer outcome than combined osseous and ligamentous injuries. The mean American Orthopedic Foot and Ankle Society Midfoot Score (AOFAS) score was 77 indicating an excellent outcome.

Polylactide screws have also been used in 14 patients with a mean follow up of 20 months and no patient was noted to have a soft tissue reaction to the screws, loss of reduction or osteolysis (50).

The potential advantage of plate fixation rather than tranarticular screw fixation is less damage to the joint surface and a theoretical risk of decreased incidence of post-traumatic arthritis. Cadaveric studies have shown that 3.5 mm cortical screw fixation versus 2.7 mm ¼ tubular plate fixation are comparable at maintaining reduction of the 2nd TMT joint at weight bearing load (2).

Primary arthrodesis

The role of primary arthrodesis in the treatment of acute TMJC injuries is yet to be established. Recent evidence reviewed by the AOTrauma group concluded that evidence from two randomized controlled trials suggests a marked increase in the need for re-operation in those receiving ORIF compared with arthrodesis, with a risk increase of approximately 300%. Anatomic reduction was achieved initially by either method, and no definitive conclusions can be made about a preference in terms of functional outcomes although they appear to be better for arthrodesis, regarding pain (3).

Henning et al. performed a randomized controlled trial (Level II evidence) comparing primary arthrodesis with primary open reduction and internal fixation in 40 patients with a mean follow-up of 24 months (21). Primary arthrodesis resulted in a significant reduction in the rate of follow-up surgical procedures if hardware removal is routinely performed with no significant difference in SF-36 and Short Musculoskeletal Function Assessment outcome scores when compared to primary open reduction and internal fixation. No difference in satisfaction rates was found between primary open reduction and internal fixation and primary arthrodesis at an average of 53 months in a phone survey. Ly and Coetzee performed a prospective, randomized clinical trial (Level II evidence) comparing primary arthrodesis with traditional open reduction and internal fixation (27). The mean AOFAS Midfoot score was 68.6 points in the open reduction group and 88 points in the arthrodesis group ($p < 0.005$). Five patients in the open reduction group had persistent pain with the development of deformity or secondary osteoarthritis, and they were eventually treated with arthrodesis. The patients who had been treated with a primary arthrodesis estimated that their post-operative level of activities was 92% of their pre-injury level, whereas the open reduction group estimated that their post-operative level was only 65% of their pre-operative level ($p < 0.005$).

Surgical technique

The TMJC can be exposed via two dorsal incisions (Fig. 5), though care should be taken not to undermine the skin in order to preserve the relatively narrow skin bridge that is created. The first incision is centred over the 2nd TMT joint and extensor hallucis longus (EHL) is retracted medially and the extensor digitorum brevis along with the neurovascular bundle protected laterally. This gives access to the 1st and 2nd TMT joints as well as the intercuneiform joints. The lateral incision is centred over the 4th TMT joint and the superficial branch of the peroneal nerve is at risk. This gives access to the 3rd – 5th TMT joints. An additional medial stab incision can be used in order to achieve fixation if intercuneiform instability exists. An alternative extensile dorsal approach centred at the base of the 2nd toe to the centre of the ankle can sometimes be used for combined foot and leg injuries but more care has to be taken to avoid undermining skin in order to prevent tissue necrosis.

The order of fixation in TMJC injuries is important. As a general rule fixation should be performed from proximal to distal and medial to lateral to ensure anatomic reduction of the entire TMJC. If there is instability present between the medial and intermediate cuneiforms this should be stabilized first via a stab incision medially and screw fixation. The 1st TMT joint is reduced and can be held with a K wire that stabilizes the medial column prior to screw fixation. Following this the use of a percutaneous clamp placed on the base of the 2nd metatarsal and medial cuneiform reduces the middle column. If this is not achievable with closed manipulation then open reduction is necessary to be sure to obtain an anatomical reduction. The only situation where the order of stabilization changes is in the presence of a cuboid fracture where the length of the lateral column of the foot is shortened and this needs to be addressed before medial and middle column fixation.

Post-operative regimen and timing of Hardware removal

After initial internal fixation or arthrodesis the patient is non weight bearing for the first 6 weeks and protected weight bearing in a walking boot after this if the wounds have satisfactorily healed. This is rather dependent on the case and the stability of the fixation. The “non walking boot” is usually used for the first 6 weeks and a custom orthotic to support the medial longitudinal arch used after this until the patient experiences no pain on stress testing. This can take up to 9 months. Ligamentous injuries take longer to heal than osseous injuries and therefore hardware is left *in-situ* for at least 4 months in the internal fixation group (35).

Navicular fractures

The two main aims of treatment are:

1. To maintain the articular congruity of the talonavicular and naviculocuneiform joints.
2. To maintain length of the medial column of the foot.

The dorsomedial approach to the navicular can be used for multifragmentary, displaced, intra-articular fractures. The skin incision is made in the interval between the TA and EHL tendons and the extensor retinaculum divided. However, superficial to the retinaculum are branches of the superficial peroneal nerve and care should be taken handling them due to the incidence of superficial neuroma formation. Dissection between the TA and EHL tendons is performed. Full thickness skin flaps should be maintained and dissection to periosteum performed. The dorsalis pedis and deep peroneal nerve are near, and deep, to the EHL tendon. In a high-energy injury, the comminution may be severe. Care should be taken not to strip the periosteum or joint capsule from any small pieces. If a piece is attached to a proximal piece of joint capsule, then the best course of action may be to flip it proximally so as not to disrupt its soft-tissue attachments. Once the joint is reconstructed, this “trap-door” piece can be reduced and fixed.

In addition to the dorsomedial approach the medial utility incision can also be utilized often in addition in severe fractures. It provides access to all the medial structures of the foot and utilizes a safe plane between the tibialis posterior and the tibialis anterior. There are no major neurovascular structures in this region.

Fig. 5. Two dorsal incision approach to obtain anatomical reduction and internal fixation of the tarsometatarsal joint complex. Also note the medial incision for hardware insertion.

In simple fractures, reduction compression devices may lead to over compression and loss of shape and articular congruency. If the tips of the reduction clamp are positioned to far proximally, a malreduction is usually the result. The tips should be positioned in such a way as to provide even compression across the fracture. The simple fractures can be fixed with cannulated lag screws with or without washers depending on bone quality.

Medial column length is crucial in maintaining the shape of the medial arch of the foot. If the navicular injury has resulted in comminution a loss of length can result. Treatment options in this situation are navicular specific plating or bridging of the fracture. Hardware from the talus to the cuneiforms with or without bone graft will attempt to maintain length of the medial column and overall shape and alignment of the foot. If this is not an option primary fusion can be performed but as mentioned previously has a significant consequence on hindfoot motion effectively eliminating it.

The form and function of the foot is dependent on the normal relationship between the medial and lateral columns. If the relative lengths of the medial and lateral columns are not maintained, foot deformity results. Relative shortening of the medial column leads to a *pes cavus* deformity and relative shortening of the lateral column leads to a *pes planus* deformity.

Cuboid fractures

Missed fractures or non-operative treatment of displaced cuboid injuries can lead to shortening of the lateral column with subsequent *pes planus* deformity, which may be painful. Non-displaced fractures around the cuboid can be treated non-operatively with immobilization, with or without restriction of weight bearing. In cases of lateral column shortening or articular displacement, operative reconstruction is advised. Usually, only one articular surface of the cuboid is impacted or comminuted, equally affecting the calcaneocuboid or the tarsometatarsal joint surfaces. Starting from the medial fragments, the affected articular surface should be reconstructed using the intact side of the joint as a model. Similarly to navicular fractures surgical treatment options in this situation are cuboid specific plating or bridging of the fracture either with internal or external fixation (54).

AREAS OF TREATMENT UNCERTAINTY

1. There remains debate regarding the best mode of surgical treatment for unstable TMJC injuries. Based purely on current evidence, "a primary fusion for ligamentous TMJC injuries appears more successful at eliminating pain and decreasing the risk of further surgical procedures considerably compared to primary open reduction and internal fixation".

2. There is some concern however regarding primary fusion in athletes who sustain a TMJC injury via a lower energy sporting injury who may be better served by open reduction and internal fixation if planned return to sport at a higher level is anticipated.

3. There is no evidence to guide which fixation method is superior for a pure ligamentous injury compared to a combined osseous and ligamentous injury. How soon after these injuries can hardware be removed and return to sporting activity be resumed is unknown.

4. What will be the incidence of post-traumatic arthritis and subsequent fusion in patients treated with primary open reduction and internal fixation? Are there any prognostic factors that may be able to stratify this risk?

5. If primary fusion is performed as initial treatment for a TMJC injury what is the risk of developing post-traumatic arthritis elsewhere in the foot and ankle? Should this procedure be reserved for older patients who sustain this injury?

FINAL GUIDELINES AND RECOMMENDATIONS

1. Multiple authors have correlated worse outcomes with non-anatomic reduction of unstable TMJC injuries and therefore to ensure anatomic reduction surgical fixation is required – Level II – IV evidence.

2. TMJC injuries should be treated with open reduction and internal fixation with combination of screw and K wire fixation – Level III/IV evidence.

3. TMJC injuries should be treated with primary arthrodesis – Level II – IV evidence.

4. Athletes/high demand patients should be considered for open reduction and internal fixation rather than primary arthrodesis – insufficient evidence.

5. Stable TMJC injuries, which remain anatomically reduced, can be treated non-operatively – Level IV evidence.

The current evidence available to determine best treatment for midfoot injuries is weak. An algorithm based on this evidence is shown in (Fig. 6). More Level I evidence is needed to answer some of the areas of treatment uncertainty presented here and this may only be possible by performing large multicentre prospective randomized controlled trials in the future.

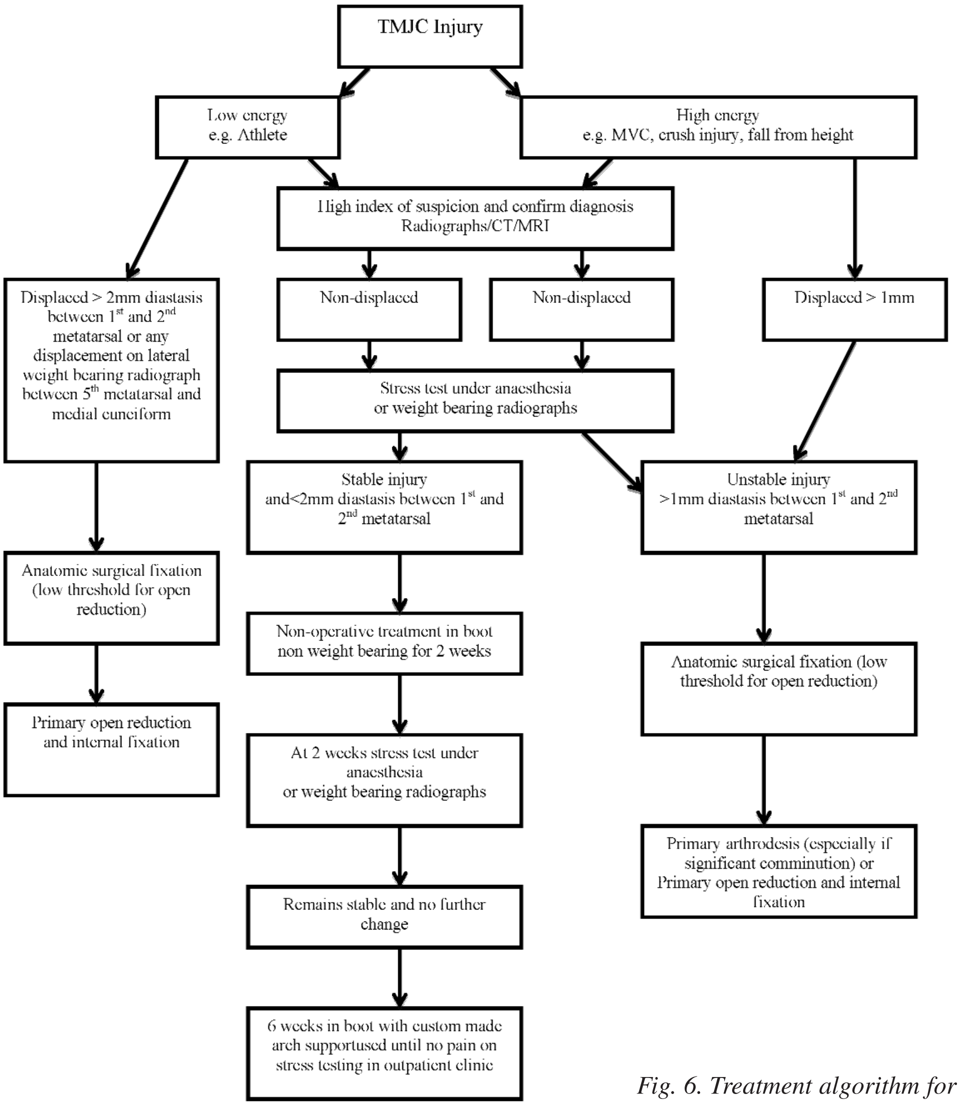

Fig. 6. Treatment algorithm for TMJC injuries.

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