Management of Midfoot Fractures and Dislocations

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Abstract

Purpose of Review To outline the classic and recent literature of midfoot fractures and dislocations.

Recent Findings There has been an evolution of implant technology to include mini-fragment fixation, suture fixation, and staples. Their efficacy is still being elucidated in the literature. Also, there has been a recent push for primary fusion, which we will discuss.

Summary Open reduction internal fixation of the midfoot remains to be the gold standard treatment, to which all other treatments are compared. It remains to be seen if adjunct fixation techniques are efficacious enough to provide a good result. Further study is needed to determine which patients are likely to progress to debilitating arthrosis and require fusion.

Keywords Lisfranc · Cuboid · Navicular · Fracture · Dislocation · Midfoot

Introduction

Injuries to the foot have long been recognized as a difficult problem to manage. These injuries are subtle and commonly missed. With experience, we have improved our diagnostic accuracy. As our recognition of pathology has improved, the data in the literature has expanded to aid our decision-making. With our greater understanding of midfoot injuries and constant evolution of implant technology, we currently have more decisions to make in treating these injuries.

Navicular Fractures

Fractures of the tarsal navicular have classically been separated into two distinct categories, acute and stress fractures. They are two distinct entities; therefore, their presentation, diagnostic workup, and treatment will be different.

The etiology of the navicular stress fracture has not been determined. The theory focuses on the transition of the distal articulation of the navicular with the medial and middle cuneiform bones to the single proximal articulation of the navicular with the talus. Since load is transferred from the first and second metatarsals independently into their respective cuneiform, the medial and lateral portions of the navicular are not loaded evenly. Also, the vector of the compressive force from the talus passes asymmetrically through the medial navicular. This results in a shear force in the central portion of the bone between the cuneiform articulations. The stress fractures occur predictably at this transition point in the navicular in the sagittal plane [1]. The navicular is surrounded by a plexus of blood vessels, which penetrate the bone in a radial direction from both the anterior and posterior tibial arteries. Although the opportunity for blood flow to the navicular is great, the central third is relatively avascular and is more susceptible to injury [2, 3]. The risk factors which have been described include a long second metatarsal, metatarsal adduction, and equinus contracture [4].

The stress fracture of the tarsal navicular has only recently been recognized as a distinct entity. In 1970 and 1975, case reports were published describing the navicular stress fracture [3]. Then in 1982, a series of 21 cases was published by Torg et al. who described their experience in treating this condition and devised the following guidelines. Patients with uncomplicated partial stress fractures and non-displaced complete fractures should be treated with immobilization in a cast and non-weightbearing for 6 to 8 weeks. Patients with displaced fractures and non-united fractures should be treated with internal

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fixation and bone grafting. It was also noted if patients continued to weight bear during immobilization, they were more likely to fail treatment [3].

More recently, Torg et al. reported a meta-analysis in 2010 on operative versus non-operative treatment of navicular stress fractures. They found no statistically significant difference between the two treatment strategies, which included return to activities. They concluded that non-operative, non-weightbearing management should be the standard of care for both partial and complete fractures of the tarsal navicular. It reinforced the finding that weightbearing was statistically significantly more likely to lead to treatment failure [5].

Although non-operative treatment has been reported as the standard for the navicular stress fracture, in 2017, Saxena et al. published their results showing operative intervention could be useful in select situations as the first-line treatment [6]. They reported on 62 fractures in athletes, 34% of whom were elite or professional. They showed CT was the study of choice and was able to make the diagnosis 100% of the time, while MRI was only 71% accurate. The patients who were indicated for non-operative treatment either had a stress reaction on MRI and no changes on CT or had a dorsal cortical fracture on CT. This consisted of 6 weeks non-weightbearing in a short leg cast or boot, followed by 2–6 weeks weightbearing in a boot until pain free. The patients indicated for surgery had a fracture line that extended into the navicular body or complete propagation from the dorsal cortex to any other cortexes. The procedure performed was an open reduction and internal fixation with a screw after debriding the fracture site and bone grafting. They found a return to sport of 91.9%, and the time frame to return to sport was 3.97 months in patients treated non-operatively and 4.56 months in patients with open reduction internal fixation (ORIF). Previous reports outlined a range of return to sport from 4.9 months with non-operative treatment and 5.2 months with ORIF [5].

Based on the current evidence, non-operative management is the treatment of choice for partial and complete non-displaced stress fractures of the tarsal navicular. ORIF with bone grafting should be reserved for the patients with displaced complete stress fractures or those who failed their initial treatment. The most important point to take away from the recent evidence is those patients with only MRI findings or a dorsal cortex irregularity will return to sport 1 month earlier treated non-operatively than anyone treated with surgery. We do not see a significant improvement in a return to sport with an expansion of the surgical indications.

The tarsal navicular is the keystone of the medial column and bears a majority of the load in the tarsal complex with weightbearing [7]. There have been multiple classification systems that are described to guide treatment of these fractures [8, 9]. These classifications use the fracture pattern to predict the resultant instability of the midfoot. This considers not only the navicular fracture itself, but also the adjacent ligamentous

instability, which commonly occurs with certain fracture patterns.

The most referenced classification is by Sangeorzan et al. in 1989. Their classification associated fracture types with common ligament injuries (Table 1). In their series of 21 patients, all were treated operatively. The fragments were reduced and held with lag screws when amenable, but medial column bridge plating was used when there was a significant amount of medial column comminution. This was done either with a mini-external fixator or with screws/pins traversing from the navicular to the adjacent cuneiforms, cuboid, or talus. All bridging hardware was planned for subsequent removal. All fractures were reported to unite but there was often resulting pain and deformity. This was correlated to the quality of reduction and type of fracture, which are very much related. A satisfactory reduction, defined as restoration of > 60% of the joint surface in AP and lateral joint planes, was achieved in 100% type 1, 67% type 2, and 50% type 3 fractures. They concluded the classification system was useful in predicting patient outcome, which was increasingly subjectively poor with more severe injuries; however, most patients were able to perform routine activities with no pain [8].

As our understanding of these injuries has improved, there are larger recent case series reporting on the outcomes. Coulibaly et al. presented a retrospective series of 88 patients with 90 fractures where 49 were treated non-operatively and 41 were treated operatively. Although the indications for non-operative treatment were not outlined, the accepted expert opinion guidelines are joint incongruity > 2 mm, medial column shortening > 3 mm, joint instability, open fracture, compartment syndrome, and skin at risk. When non-operative treatment is selected, one must be certain there is no ligamentous instability that could be diagnosed on weightbearing radiographs or a stress fluoroscopic examination [4]. When a fracture was treated non-operatively, the patient is placed in a short leg cast or orthosis and made toe-touch weightbearing for 10–12 weeks.

Their operative technique was an ORIF with mini-fragment plate fixation with autologous or allogenic bone grafting of any defects. This technique was first reported by Evans et al. [10]. When the joint surfaces were unreconstructable, primary arthrodesis was preferred. They had 56 cases of secondary arthrosis, which was highly correlated to ORIF and was a function of the severity of the initial injury. Twenty-five patients underwent subsequent hardware removal. Forty-three percent still reported pain at a final follow-up of 52 weeks. Sixty-nine percent were able to wear normal shoes, which was correlated with a return to work with no restrictions. Inability to return to work was correlated with pain, secondary arthritis, poor reduction, and BMI > 35 [11•]. Again, their findings are consistent with the previous literature that quality of reduction is the most significant factor in the surgeon's control in the outcome of these patients.

Table 1 Classification associated fracture types with common ligament injuries

Navicular fracture classification		
Type	Fracture line	Associated instability
1	Coronal plane, < 50% of body	None
2	Dorsal-lateral to plantar-medial	Dorsal talonavicular ligament torn
3	Central or lateral comminution	Cuneonavicular and calcaneocuboid ligaments torn

These findings have been corroborated by Schmid et al. as well. Their conclusion in a series of 24 operatively treated patients was the outcome is closely related to fracture severity, especially the degree of joint involvement [9]. In the setting of a highly comminuted navicular fracture, bridge plating the medial column of the foot with mini-fragment fixation has been described to maintain stability. The plate can span from the talus to the first metatarsal and the screws obtain fixation in the cuneiforms and cuboid as needed [7]. This is the authors' preferred technique; an example can be seen in Fig. 1a–d.

Based on past and current evidence, the treatment of navicular fractures remains a difficult problem to manage. The severity of the initial injury is most important in predicting the final outcome of these patients, which includes pain, activity level, and ability to return to work. It is important to be vigilant in the diagnosis of midfoot instability with isolated navicular fractures since it has been shown some fracture patterns are associated with predictable ligament injuries. Improved outcomes are able to be achieved by obtaining an anatomic reduction at the time of surgery but will be limited by the extent of articular damage. There are no studies to date comparing primary arthrodesis to ORIF, as this may be an option for the unreconstructable joint surface [9].

Cuboid Fractures

The principles of acute cuboid fracture management are very similar to the navicular, as described previously. Cuboid fractures account for a small percentage of foot fractures and as a result have not been discussed much in the literature. The indications for operative treatment are open fracture, displacement of > 2 mm, > 1 mm articular displacement, and lateral column instability [7]. One of the first case series describing treating these fractures was by Sangeorzan et al. in 1990. They described four cases treated with open reduction and internal fixation. Three cases had a bone void large enough to require grafting of the fracture site. At the time of surgery, they noted the proximal or distal articular surface was driven into the center of the bone. The authors recommended ORIF of these fractures, with structural iliac graft if they are very comminuted [12].

In 2002, Weber and Locher published the results of a series of 12 patients who were operatively treated for displaced cuboid fractures. Ten patients had another concomitant midfoot injury. They noticed two distinct fracture patterns, most commonly (11 of 12 patients) was an articular impaction from metatarsals 4 and 5. One patient sustained a burst of the cuboid body itself resulting in shortening of the lateral column. The operative technique was an incision centered over the intermetatarsal space of 4 and 5 to the tip of the fibula. An external fixator was used to regain length and anchored from the calcaneus to the fourth metatarsal. The lateral wall was opened and the joint surface was reconstructed. Defects were reconstructed with bone graft and fixation was with two 2.0 mm plates. If the column was not stable after the distractor was released, then the frame could be left for 4 weeks. They reported good results for the reconstruction of the joint surfaces and length as well as return to function. Any residual symptoms were usually related to the concomitant midfoot injuries. They concluded in regard to the fracture of the cuboid, deformity and disability can be prevented by ORIF [13].

The largest and most recent study was completed by Fenton et al. in 2016. It was a retrospective case series of 192 fractures that were treated operatively and non-operatively. They classified the fractures into five major types. Type 1 is an avulsion fracture, was most common (48%), and was treated non-operatively. Type 2 is an entirely extra-articular fracture and was not associated with shortening of the lateral column; it comprised 13% of the cohort and was also treated non-operatively. Type 3 fractures consisted of intra-articular fractures involving the calcaneocuboid or the metatarsal-cuboid joints. Six percent of fractures were type 3 and were treated with ORIF and bone grafting of any joint depression (Fig. 2a–c). Type 4 was a fracture of the cuboid with a concomitant injury to the tarsometatarsal complex. This was 18.2% of the fractures, treated with ORIF of the cuboid, and stabilization of the tarsometatarsal complex. Type 5a was a cuboid fracture associated with shortening of the lateral column and 5b involved shortening of both columns. Their respective occurrences were 6.3 and 7.3%, and they were treated with reestablishing the length of the involved columns with ORIF and bridge plating or external fixation. It is important to note swelling may delay surgical intervention and the length of the midfoot can be temporarily stabilized with either external fixation or K wire fixation [14•]. In the authors' practice, these

Fig. 1 **a, b** AP and lateral radiographs demonstrating medial column instability with a comminuted navicular fracture, first MTP dislocation, first, second, and third TMT instability. **c, d** AP and lateral radiographs showing medial column stabilization with a bridge plate and ORIF of second and third TMT

are our operative guidelines, and in our experience, K wires have been more reliable in maintaining reduction than external fixation. Further studies need to focus on the outcomes of patients with these injuries after intervention. To date, we only have the small retrospective case reviews to guide our decision-making.

Tarsometatarsal and Cuneiform Injuries

Although these injuries are relatively infrequent, there has been a large focus on understanding them in the literature. The diagnosis of pure ligamentous instability can be missed up to 20% of the time [7]. Misdiagnosis must be avoided, and we must be vigilant in making the diagnosis based on history, physical, and imaging studies. The physician needs to have a high index of suspicion with any patient reporting pain in the midfoot who sustained an axial load through the foot. This can occur in both high energy mechanisms such as motor vehicle accidents and low energy mechanisms related to some sports [15]. Sports such as soccer, rugby, basketball, martial arts, and horse riding have a relatively high incidence of injuries to the tarsals and metatarsals, and there needs to be a high index of suspicion when evaluating these athletes describing foot pain

after injury [16]. Patients will present with swelling, pain, and inability to bear weight, especially on the toes [17]. Plantar ecchymosis has been noted to be associated with an injury to the tarsometatarsal complex [18]. One must not be complacent if it is not present though, as low energy mechanisms in athletes seldom have it [17]. On examination, three provocative tests have been described to be associated with these injuries: pain with dorsiflexion and abduction of the forefoot, the TMT-compression test, and the Abduction-Pronation test [19]. The findings on initial radiographs can be very subtle or quite dramatic. A fleck sign can be present, which is an avulsion of the Lisfranc ligament. If no abnormalities are identified, then a stress view is performed with the patient bearing as much weight as possible and comparing the film to the normal side to look for subtle differences in the joints [19]. Another tool is an examination under anesthesia if a patient cannot tolerate a stress exam. Under fluoroscopy, the pronation abduction test will demonstrate instability [20]. A CT of the foot can help identify subtle fractures in the midfoot but will not be able to identify instability [7]. MRI has been shown to be an adjunct tool with a sensitivity of 94%, specificity of 75%, and positive predictive value of 94% in predicting instability when the plantar ligament between the medial cuneiform and bases of the second and third metatarsal was disrupted [21•]. The

Fig. 2 a–c AP, oblique, lateral radiographs showing an ORIF of the cuboid stabilizing the lateral column and medial column with a plate including screws traversing the Lisfranc joint to stabilize the TMT complex

authors have been most successful in diagnosis by using history and physical, with high index of suspicion, quality imaging including weightbearing films, combined with a stress exam with fluoroscopy under anesthesia.

The focus of classification systems has been displacement of the tarsometatarsal complex in the coronal plane. The first description was by Quénu and Küss in 1909. They described three injury patterns, homolateral, partial, and divergent [7]. In 1986, Myerson et al. expanded the classification to include subtypes which included more partial injuries [22]. Recently, Lau et al. set out to expand the classification system to include sagittal displacement and determine if the sagittal instability was related to the patient outcome. They showed sagittal instability was not significant in predicting outcomes but the deformity in the coronal plane and number of column involvement was correlated [23]. This suggests our current models of fracture classification are helpful in predicting outcomes.

It is widely accepted that operative treatment is required for patients with displaced fractures and dislocations of the tarsometatarsal complex. In 2015, Crates et al. reported on their experience of operative compared to non-operative treatment for the subtle Lisfranc subluxation. All 36 patients were symptomatic and had positive physical exam findings and varying degrees of radiographic instability ranging from none, to medial cuneiform rotation only, to subluxation of the second metatarsal. All of the patients were initially treated with a short leg orthosis and weightbearing as tolerated for 6 weeks and then progressed back to sport. If they were persistently symptomatic, then they were indicated for surgery. All patients who were radiographically stable responded well to non-operative treatment. If there was widening of up to 2 mm between the first and second metatarsals with no subluxation, medial cuneiform rotation, or widening plus medial cuneiform rotation, then only half of the patients responded and the other half went on for surgical stabilization. None of the patients with any subluxation of the second metatarsal responded and all required surgical stabilization. The patients were stabilized either with a mini-tightrope or with screw stabilization. The only difference between the two groups was none of the 11 tightrope patients required hardware removal and 7 of 9 treated with screws did. The authors concluded that all patients with subluxation of the second metatarsal must be stabilized but more study is needed to determine which patients with subtle widening between the first and second metatarsals or rotation of the medial cuneiform require surgery. These patients can undergo a trial of non-operative treatment, but if they remain symptomatic, they may require surgical stabilization. Also, screw and tight rope fixations are equivalent except for reoperation rates [24].

Currently, there are many options of implant choice for stabilization of the midfoot. Now, we have the option not only of screw fixation, but also of suture anchor/buttons, nitinol staples, and mini-fragment plates. Although there are no level 1 studies comparing various implants, there is data in the literature to guide the surgeon. Although nitinol staples are straightforward to place, their ability to maintain a reduction has not been proven. The manufacturers do advertise the

Fig. 3 **a, b** Oblique pre- and postoperative radiographs showing a fracture of the medial and middle cuneiform with medial column instability and subsequent fixation with bridge plates including a screw traversing the lisfranc joint

ability to obtain compression, but Yu et al. have shown the staple is inferior in restoring forefoot plantar pressure after a simulated first tarsometatarsal joint fracture dislocation in a cadaver specimen. This is in contrast to fixation with a quarter tubular plate or screws alone which was able to return the forefoot pressure distribution to normal [25]. Lau et al. reported on their findings of 62 patients comparing screw fixation, dorsal spanning plate fixation, or a combination of these techniques in a retrospective fashion. They found patients stabilized with dorsal spanning plates were more likely to have

wound problems compared to those with screws alone, but this was not statistically significant. Also, the hardware removal rate was similar. The outcome of the patients treated with spanning plates and screw fixation was the worst, but this was most likely to these patients having more severe initial injuries. They concluded dorsal spanning plates are a reliable option for obtaining fixation, as their success and complications are similar to the gold standard of screw fixation. The advantage of plates lies in maintaining joint surface and not violating it with instrumentation [26] (Fig. 3a, b).

Fig. 4 **a, b** Oblique and lateral radiographs with comminuted navicular and cuboid fractures along with second and third TMT instability. **c, d** Oblique and lateral fluoroscopic images showing plate fixation of the navicular, cuboid, bridge plate fixation of the second and third TMT, and ORIF of the medial to lateral cuneiforms. **e** Oblique radiograph showing removal of all bridging hardware

There has been a recent interest in the use of suture button fixation for these injuries. Authors are interested in this implant because it may have the ability to maintain a reduction and maintain physiologic motion once the injury has healed. This has the potential to eliminate the need for a second hardware removal surgery, reduce the potential posttraumatic arthritis, and decrease pain patients feel after these injuries. In 2009, Panchbhavi et al. showed screw fixation and suture button fixation were equivalent in maintaining stability in cadaveric specimens after the Lisfranc ligament was severed [27]. Ahmed et al. also conducted a cadaveric study comparing the suture button to screw fixation and found there was more diastasis (1 mm on average) in the suture button group compared to that in the screw group, which was statistically significant. It is unclear if this will impact clinical outcomes [28]. These findings were confirmed by Pelt et al. in their cadaver study as well [29]. There are small case series showing the efficacy of the suture button, but more studies are needed to determine if these constructs provide sufficient stability to lead to a reliable good outcome compared to the gold standard of screw fixation [30].

The current gold standard for management of tarsometatarsal joint injuries is screw fixation. If there is a great deal of comminution, bridge plates are the implant of choice. The downside is the need for removal but they will reliably maintain the reduction and allow earlier weightbearing. Based on the current available literature, the authors believe that more study is needed in the use of adjunct fixation methods, such as suture-based fixation devices.

Lastly, there has been a push for primary arthrodesis in the treatment of tarsometatarsal joint injuries. Ly et al. published the results of a randomized control trial comparing arthrodesis and ORIF in the pure ligamentous Lisfranc injury. They reported patients treated with a primary arthrodesis had better functional outcome scores and did have less need for secondary surgeries. It is important to note that only ligamentous Lisfranc injuries were included and this data cannot be extrapolated to patients with fracture dislocations or multiple joint involvements. Arthrodesis of both the medial and intermediate columns is not recommended [31]. Henning et al. conducted their own level 1 trial comparing ORIF and primary arthrodesis. It is important to note they included patients with fractures of the foot into their study population. Twenty-two of the 32 total patients had one or more metatarsal base fractures, 3 patients had a concurrent cuboid fracture, 1 patient had a navicular fracture, and 7 had one or more cuneiform fractures. They found no difference in patient satisfaction or functional outcome scores between the two groups. The patients in the ORIF group did have a higher incidence of need for secondary procedures, but part of the treatment course was to remove the hardware at the third month after ORIF [32••]. In the authors' experience, ORIF provides the patient the best chance to restore normal foot mechanics (Fig. 4a–e). Although studies

have shown good results with primary arthrodesis, ORIF is preferred in certain patient subsets, especially in the young, active, athletic patients [33]. In our experience, ORIF with fixation that spares the joints has been able to get our patients back to weightbearing and sports faster with a decreased need for hardware removal. We do not currently have a reliable way to predict the development of posttraumatic arthrosis after ORIF. More importantly, the long-term impact of midfoot fusion on the nearby structures such as the adjacent ankle and subtalar joints is unknown. Arthrodesis of the knee and hip joints leads to accelerated degeneration of the adjacent joints and greatly impacts gait mechanics. With that concept in mind, we must be careful with the widespread use of midfoot fusion. Until more evidence is available, the authors advocate for ORIF of these complex midfoot injuries, especially with concomitant fractures.

Conclusions

There has been a recent interest in the management of complex midfoot fractures. These injuries are rare but can be very debilitating if not treated properly. We now have many implant choices and multiple treatment options but must remain vigilant in adhering to our basic principles of fracture fixation. Every patient presents with a novel injury and situation, and it is important to make the appropriate diagnosis and tailor the treatment accordingly with the knowledge available to the surgeon.

Compliance with Ethical Standards

Conflict of Interest Both authors declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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