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Internal fixation of complex fractures of the tarsal navicular with locking plates. A report of 10 cases

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KEYWORDS
Fracture; Navicular bone of the foot; Internal fixator; CT scan

Summary
Introduction: Tarsal navicular fractures are rare and treatment of comminuted fractures is especially difficult. Since 2007, the authors have had access to 3D reconstruction from CT scan images and specific locking plates, and they decided to evaluate whether these elements improved management of these severe cases.

Materials and methods: Between 2007 and 2011, 10 comminuted tarsal navicular fractures were treated in a prospective study. All of the fractures were evaluated by 3D reconstruction from CT scan images, with suppression of the posterior tarsal bones. The surgical approach was chosen according to the type of lesion. Reduction was achieved with a mini-distactor when necessary, and stabilized by AO locking plate fixation (Synthes®). Patient follow-up included a clinical and radiological evaluation (Maryland Foot score, AOFAS score). Eight patients underwent postoperative CT scan.

Results: All patients were followed up after a mean 20.5 months. Union was obtained in all patients and arthrodesis was not necessary in any of them. The mean Maryland Foot score was 92.8/100, and the AOFAS score 90.6/100. One patient with an associated comminuted calcaneal fracture had minimal sequella from a compartment syndrome of the foot.

Discussion: The authors did not find any series in the literature that reported evaluating tarsal navicular fractures by 3D reconstruction from CT scan images. The images obtained after suppression of the posterior tarsal bones systematically showed a lateral plantar fragment attached to the plantar calcaneonavicular ligament, which is essential for stability, and which helped determine the reduction technique. Locking plate fixation of these fractures has never been reported.

Conclusion: Comminuted fractures of the tarsal navicular were successfully treated with specific imaging techniques in particular 3D reconstructions of CT scan images to choose the surgical approach and the reduction technique. Locking plate fixation of the navicular seems to be a satisfactory solution for the treatment of these particularly difficult fractures.

Level of evidence: Level IV.

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Introduction

Navicular bone fractures of the foot are rare [1], but can have serious consequences because of the essential role of the talonavicular joint. This joint is associated with subtalar articulation to form the acetabulum pedis [2], which influences mobility of the entire foot. The "calcaneo-pedis block" [3] pivots on the talar head at the acetabulum pedis or the coxa pedis. The talonavicular joint is the most mobile of all the joints in the mid-foot [4].

Comminuted fractures are particularly difficult to treat and if internal fixation is impossible, certain authors recommend arthrodesis as the first or second line of treatment [1,5]. Partial avascular necrosis alone or associated with secondary collapse is frequent after a tarsal navicular fracture [1,5]. Since 2007, we have been performing 3D reconstructions from CT scan images and have access to locking plates that are specifically for navicular fractures1. This study evaluated whether 3D reconstructions could be used for surgical planning to obtain optimal reduction and if the use of locking plates resulted in stable fixation and reduced the risk of necrosis.

Materials and methods

Between 2007 and 2011, we performed a prospective study of 10 comminuted tarsal navicular fractures treated by locking plate in 10 men, mean age 29 years old (Table 1). All fractures were evaluated by preoperative 3D reconstruction of CT scan images, with suppression of the posterior tarsal bones to clearly visualize each of the different fragments of the fracture. Patients then underwent surgery by an approach that was adapted to their type of lesion. The articular capsule was opened on the side of the talus to preserve navicular vascularization as much as possible (Fig. 1). In six cases, reduction was obtained (Fig. 2) with the help of a mini-distactor between the head of the talus and one of the cuneiform bones (medial: three times, intermediate: twice and lateral, once). After disimpaction and temporary stabilization of the intermediate fragments with pins that were placed under visual control, final reduction of the reconstructed articular block against the lateral plantar fragment was obtained by releasing traction and using a pointed reduction forceps, with the plantar point slipped under the navicular above the flexor tendons (Fig. 3) and the dorsal point either in a dorsomedial or a dorsolateral position depending on the type of fracture. Reduction was obtained under fluoroscopic control. Stable fixation was then obtained with a locking plate (Fig. 4). The plate was placed in a dorsal, laterodorsal or mediolateral position depending on the type of fracture. It was slipped under the soft tissues, without releasing the dorsal periosteum to preserve vascularization as much as possible. The screws on these plates are perpendicular to the plate but the plate must be formed and cut to the necessary length. The plate must be curved so that the angle of the screws is correct.

1 Navicular locking plate Synthes™, Synthes-France, DepuySynthes, Johnson&Johnson Company, 1078, avenue Oehmichen, 25460 Etpues, France.

Figure 1 Sagittal CT scan with a CT soft-tissue window of a dislocated fracture of the tarsal navicular. The surgical approach (arrow) is achieved by opening the articular capsule on the side of the talus to preserve vascularization of the navicular bone.

The screws that were closest to the talonavicular joint were directed at a slightly forward angle so they do not penetrate the extremely concave surface of the joint (Fig. 5). The most distal screws, on the other hand, are directed at a slight angle towards the back and screwed into the plantar fragments near the articular surface.

In one case with fracture-dislocation and significant plantar comminution, the most medial screws were directed towards the cuboid and screwed several millimeters into the bone to obtain sufficient stability. No additional talonavicular pinning was performed. A postoperative CT scan was obtained in 8/10 cases.

All patients were immobilized in a splint then a plaster cast. Progressive weight-bearing was allowed after 6 weeks except in one case (2 months) due to associated lesions. The patients underwent a clinical (Maryland Foot score [6], AOFAS midfoot score [7]) and radiological evaluation at the final follow-up.

Results

3D reconstruction from CT scan images with suppression of the talus and the calcaneus (Fig. 6) showed a more or less voluminous lateral plantar segment, which was still attached in all cases, even in dislocation-fractures (6 cases). This fragment included a more or less marked bone spur corresponding to Sarrafián’s navicular “beak” [2]. The location of the comminution determined the surgical approach, which was associated in certain cases with a second surgical approach. The surgical approaches were adapted to the type of lesion: dorsomedial, in three cases, dorsal in two cases and both medial and dorsolateral in five cases. There were no bone grafts.

Reduction was considered to be anatomic on standard X-rays in two patients who did not undergo a CT scan. In the eight patients who underwent CT scan, reduction was anatomic in four cases, and
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Table 1 Data summary.

<table>
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<th>No.</th>
<th>Age (months)</th>
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<th>Follow-up (months)</th>
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<th>Approach</th>
<th>Hardware failure</th>
<th>Plate removal</th>
<th>Talonavicular arthritis</th>
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Average 31

Range 20-53

6-49

MCA: motor cycle accident.
nearly anatomic (1–2 mm step on an intermediate fragment of less than 7 mm) in four cases. There were no postoperative infections or vascular or nerve complications.

A dorsal fasciotomy was necessary in one patient with a compartment syndrome of the foot following a complex hindfoot trauma. All patients had a mean follow-up of 20.5 months (6–49). There was no secondary displacement. Evaluation of X-rays only showed one broken screw in the entire series. Union was obtained in all fractures, and no secondary arthrodesis was necessary. Nine patients were able to return to work after a mean 4.5 months (3–6) (one patient was not working before surgery). The mean Maryland Foot score was 92.8/100 (82–100), and the AOFAS score was 90.6/100 (87–100).

The patient with the most medial screws, that were inserted into the cuboid bone (case No. 5 in Table 1), presented with a Maryland Foot score of 95/100 and an AOFAS score of 90/100. Talo-calcaneo-navicular (TCN) joint mobility was normal and symmetric with that of the healthy side. None of the patients presented with secondary bone collapse due to avascular necrosis but one patient presented with increased bone density of the lateral navicular, which probably corresponded to partial necrosis. There was slight dorsal osteophytosis but the joint was completely painless and TCN joint mobility was absolutely symmetric. One patient with a complex hindfoot trauma including a complex calcaneal fracture associated with and complicated by a compartment syndrome of the foot, presented with a slightly irregular joint space, without narrowing of the joint space but with an osteophytic reaction. It was well aligned, painless, but very stiff.

**Figure 2** Different key steps of internal fixation: a: initial view; b: distraction for visually controlled reduction of impaction; c: final reduction ensured by a fluroscopically controlled dorsoplantar pointed reduction forceps.

**Figure 3** 3D reconstruction of CT scan images with partial visualization of the tendons. The image of a dorsoplantar pointed reduction forceps is superimposed on this image. There is no risk of nerve or vascular tissue damage if the forceps remains in contact with the bone above the flexor tendons.

**Figure 4** Synthes™ navicular locking plate.

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Discussion

Analysis of 3D reconstructions from CT scan images was essential in treating this series of navicular fractures. The usual simple CT scan views on three planes already provide more information than standard X-rays, however, because of the concave joint facet and because of the displacement, it was difficult to obtain all the necessary elements on the same image. With 3D reconstruction and suppression of the talus and the calcaneus, we were able to clearly visualize the lateral plantar fragment (Fig. 6) in all cases, including the navicular beak which was still intact, even in fracture-dislocations. This can be explained by the insertion of a bundle of the inferior plantar calcaneonavicular ligament at this level. Dissection clearly shows this ascending bundle (Fig. 7) stretching between the calcaneal tuberosity and the navicular beak. To our knowledge, this bundle has never been described in the literature. It is not mentioned in the highly detailed article of A. Taniguchi et al. [8]. Implicitly, until now the plantar calcaneonavicular ligament or the spring ligament has only been studied for its role as a stabilizer of the head of the talus in the acetabulum pedis and therefore in local dissections of the acetabulum pedis. To our knowledge, its role as a stabilizer has never been suggested in traumatic cases. Nevertheless, we feel that it is an element that must be taken into consideration, especially in fracture-dislocations. By systematically attempting to insert one or more screws into this fragment, there was no secondary displacement in any of the cases in this series. We obtained satisfactory stability in all cases even in fractures-dislocations. In one case, it was felt that medial screws should be inserted into the cuboid bone, because the lateral plantar fragment was significantly fragmented.

Talonavicular pins, which are sometimes recommended in unstable lesions [1], were never necessary. Thus, when the screws are correctly positioned, locking plates provide stable fixation. When the fragment is large and separated by a fracture line that is above the cuboid dorsally, reduction can be easily obtained by a dorsal pointed reduction forceps. When it is small, we found that a dorso-plantar pointed reduction forceps could be used with a medial incision. The plantar point was slipped under the posterior tibial tendon above the flexor digitorum longus and the flexor hallucis longus tendons to the navicular beak thus at a distance from any nerves or arteries (Fig. 3).

We therefore used one or two of the three different surgical approaches (Fig. 8).

If the lateral plantar fragment was large, a dorsal approach could be used, centered on the area of comminution. If it was small, a medial approach was necessary to be able to use a dorsoplantar pointed reduction forceps. If there was an associated dorsolateral fragment, a dorsolateral approach had to be associated for direct visual control of reduction.

This study only includes a small number of cases, but navicular fractures are rare [1]. We only included comminuted fractures in this study because simple fractures were treated by screws and/or tension band wiring. Although the follow-up was not very long (20.5 months), the most recent study in the literature [9] reported a follow-up of 16 months (2–72). One of our patients who only had 6 months of follow-up was socially marginal and did not come to later consultations. The patient had pain during “changes in the weather”, could walk normally, with a TCN joint mobility of 2/3 and could perform a one-leg hop. The talonavicular joint was normal on X-ray.

Before the study by Sangeorzan et al. [1] (1989) reporting 20 cases of internal fixation by screws and pins, only four other cases of internal fixation of the navicular had been reported. Recently, techniques including supplementary wires [10] temporary bridging by plate on the medial column [11] or external fixation [12] have been published.

**Figure 5** Postoperative sagittal CT scan. The proximal screws are aimed forward to prevent penetrating the joint. The distal screws are aimed backwards to penetrate the plantar fragment.
Figure 6 Six examples of comminuted navicular fractures with 3D reconstructions of CT scan images and suppression of the posterior tarsus. The systematic presence of a non-displaced lateral plantar fragment in contact with the cuboid should be noted.

as case reports. The only series with internal plate fixation reported 24/30 cases over a 6-year period [9]. These were conventional plates for mini-fragments (series 2.0 or 2.4, straight or T-plates). The series included 16 comminuted fractures (Sangeorzan type 3) [1]. Four of these developed osteoarthritis, including one with necrotic bone collapse. A double surgical approach was used in half the cases. The authors stated that they preferred the risk of additional devascularization to incomplete reduction. We feel that the use of a locking plate helps reduce the risk of vascular injury because the plate is slipped under the soft tissues, without periosteal stripping. There was only one case of partial asymptomatic necrosis in the present series. In a prior series, and despite precautions taken to limit devascularization, Sangeorzan et al. [1] reported six cases of avascular necrosis out of 21 cases of screw fixation. They found an increase in bone density, which was partial in four cases and total in two, including one with osteonecrotic collapse. A locking plate cannot be considered less invasive than simple screw fixation in relation to bone vascularization. On the other hand, we feel that better evaluation of morphology by 3D reconstruction makes it possible to use the most effective procedures and prevent unnecessary devascularization. Sangeorzan et al. [1] did not have CT scan images and systematically used a simple anteromedial approach. However, in a later publication [13], they suggested adding an anterolateral approach, if there are problems visualizing the fracture. We feel that high quality reduction is essential. In our series, it was always possible to restore length to the medial column without

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secondary displacement and with no need for an associated graft.

The quality of articular reduction was considered optimal in six cases and acceptable in four. We feel that the quality of reduction is influenced by several factors:

- the quality of imaging making surgical planning possible;
- perioperative use of a mini-distractor is especially useful for direct visual control of reduction of the intermediate fragments. We used this in 2/3 cases. It is recommended by several authors [1,5,9,14];

The surgical approach was based on 3D reconstructed CT scan: a: dorsal approach alone; b: in case of medial comminution, a medial approach was necessary to control the joint and to use a dorsoplantar reduction forceps; c: in case of dorsolateral comminution, a dorsolateral approach was necessary to control the joint associated with a medial approach to use the dorsoplantar reduction forceps.

Figure 7  Dissection of a hind foot with ablation of the cuboid and cuneiform bones: a: anterior view; b: anterolateral view. The inferior bundle of the calcaneonavicular plantar ligament is clearly identified.

Figure 8  The surgical approach was based on 3D reconstructed CT scan: a: dorsal approach alone; b: in case of medial comminution, a medial approach was necessary to control the joint and to use a dorsoplantar reduction forceps; c: in case of dorsolateral comminution, a dorsolateral approach was necessary to control the joint associated with a medial approach to use the dorsoplantar reduction forceps.

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the use of a pointed reduction forceps in the dorsoplantar position was the determining factor for obtaining final reduction in 2/3 cases. Although the use of a pointed reduction forceps has been mentioned in the literature [1,5,9,14], to our knowledge its use in the dorsoplantar position has never been described.

Conclusion

It is possible to obtain good results in these rare and difficult fractures (Fig. 9). These good results are based on the quality of reduction and stable fixation. We also feel that preoperative planning is essential. 3D reconstruction of CT scan images contributes significantly to this planning. The surgeon should actively participate in obtaining these 3D reconstructions, and request suppression of the posterior tarsus or at least the talus, which is not routinely performed by radiologists. The use of a mini-distactor during surgery considerably facilitates reduction of comminuted articular fragments. Reduction against the lateral plantar fragment, which is the key to stability, can be obtained with a pointed reduction forceps in the dorsoplantar position. Locking plates provide optimal stable fixation of complex fractures, while minimizing the risks of devascularization.

Disclosure of interest

The main author (P. Cronier) is a prior member of the Foot and Ankle Expert Group of the AO-ASIF (Association pour l’étude de l’Ostéosynthèse - Association for the Study of Internal Fixation), which is a non-profit association, associated with the manufacturer Synthes™. He is regularly invited to speak at international AO courses.

Other authors declare that they have no conflicts of interest concerning this article.

References


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