Acute navicular fractures: report of two cases and review of the literature

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Summary

Introduction. The navicular bone is the keystone of the foot medial longitudinal arch and is an active participant in the transverse tarsal locking mechanism. The fusion of the talonavicular joint has been demonstrated to significantly reduce the motion of the subtalar and the calcaneocuboid joint and severely limit the excursion of the posterior tibial tendon. Navicular fractures are quite rare injuries, but, because of the importance of this bone in foot motion, undiagnosed, mismanaged, or delayed diagnosed fractures can cause serious complications.

Nowadays, the literature that describes the management of the navicular fractures is limited; open reduction and internal fixation is the gold standard for treatment of navicular fractures, but there is no consensus about the preferred technique to use in these fractures.

Case report. Two cases of navicular fracture associated with other mid-foot fracture treated with cerclage are presented. The navicular fractures were fixed with screws and a cable-wire passed circumferentially to the navicular bone through a trochanteric cable passer in order to prevent radial displacement of the fragments.

Discussion. Review of the literature analyzing the management of acute navicular fractures including surgical management and post-operative treatment.

Conclusions. The use of cerclage with cable-wire and trochanteric cable passer is a good option of treatment for navicular fractures, but the availability of different tools and hardware studied for these fractures can help guide the surgeon to use less invasive and more conservative techniques, such as cerclage, an evolving and easily reproducible technique.

Key words: navicular, navicular fractures, cerclage

Introduction

Navicular fractures are rare injuries; the midfoot fractures comprise 5% of all foot injuries, and 35.5% of these involve the navicular [1].

The navicular bone is the keystone of the foot medial longitudinal arch and is an active participant in the transverse tarsal locking mechanism; it articulates distally with the three cuneiforms with three facets, proximally with the talar head forming the talonavicular joint and laterally with the cuboid [2]. Plantar and dorsal ligaments reinforce each articulation, and further stability is provided by the posterior tibial tendon, the spring (plantar calcaneonavicular) ligament, and the deltoid ligament.

The fusion of the talonavicular joint has been demonstrated to significantly reduce the motion of the subtalar and the calcaneocuboid joint and severely limit the excursion of the posterior tibial tendon; indeed, the talonavicular arthrodesis reduces the range of motion of the subtalar joint to about 2°, eliminating the 91% of its original motion [3].

The talonavicular joint permits the three-dimensional motion between the forefoot and midfoot and for this reason an untreated navicular fracture can result in serious reduction of global foot function [4].

Because of the importance of this bone in foot motion, undiagnosed, mismanaged, or delayed diagnosed fractures can cause serious complications.

There are four types of navicular fractures: avulsion, tuberosity, body, and stress [1].

The etiology of these fracture types is not well described, and there is no unanimous consensus about the mechanisms.

Avulsion fractures are the most common, comprise around 50% of all navicular fractures, and are associated with excessive plantarflexion and inversion injuries that overload the dorsal talonavicular ligament or with eversion injuries overloading the deltoid ligament.

Tuberosity fractures are related to eversion injuries causing excessive forces applied to the posterior tibial tendon and deltoid ligament.

Stress fractures are consequences of repetitive overload or injuries, andaffect the middle one-third of the navicular body because of poor vascularization; this watershed portion is also the most vulnerable to the long-term sequelae of avascular necrosis and nonunions [2].

Body fractures usually occur with high energy trauma secondary to abrupt axial load with a plantar flexed foot or strong dorsiflexory forces acting on the medial forefoot in the setting of hindfoot eversion. During these movements, the navicular bone is trapped between the cuneiforms and the talar head and the talus acts as a battering ram as it impacts into the navicular resulting in an explosive injury with radially directed fracture lines and circumferentially displaced fracture fragments [5]. In high energy trauma, navicular body fractures are often associated with additional fractures, dislocations, or both at the same foot [6].

The body fractures have been classified by Sangeorzan in three types based on the direction of the fracture line, the direction of the displacement of the fore- and midfoot, and the pattern of joint disruption.

In type I, there is a unique fracture line transverse in the coronal plane that creates a dorsal fragment that is less than 50% of the bone height. In type II, which is the most common, the fracture line extends from dorso-lateral to plantar-medial with concomitant major fragment and forefoot medial displacement. Type III includes comminuted fractures in the sagittal plane with lateral displacement of the forefoot and often the disruption of the talonavicular and calcaneocuboid joint.

The AO classification system has classified navicular fractures into avulsion fracture (83A), partial articular fractures (83B), or complete articular fracture (83C) and these latter two have been subcategorized into simple (83B/Ca) or multisegmentary (83B/Cb).

There is scarce literature about these injuries and their management is still discussed.

Avulsion and simple nondisplaced tuberosity and body fracture are typically managed non-surgically; the displaced body and tuberosity fracture have indications for surgical repair.

The surgical indication is reserved to fractures associated with > 1 mm of joint incongruity, > 2-3 mm medial column length shortening, instability, lateral column involvement, open fracture, skin compromise and irreducible dislocations [1,7].

In the literature, different surgical management without clear consensus on the better technique have been described. This fracture presents several technical challenges to restore midfoot function. Currently, open reduction and internal fixation (ORIF) is the standard of care, although multiple options of fixation are described including isolated screws, plates, cable wire, alone or combined with other alternative current technique like K-wires, external fixation, bridge plating of the lateral or medial columns, or primary arthrodesis.

In the literature, the importance of CT of the foot to identify additional foot pathologies and to provide information for the surgical planning is reported [8].

In the literature, we were motivated by the technique used by Kupcha and Naidu, and decided to use cerclage wire to fix navicular fractures; we wanted to present two different cases in which we used screws to reduce the navicular body fracture associated with a circumferential cerclage wire to reduce the radial displacement of the fragments.

Vicenza hospital is a Level 1 Trauma Center which performs 1600 orthopedic trauma-related procedures per year. In all, 67 foot fractures were surgically treated between 2019-2021; 5 fractures were recorded as navicular fractures of which two cases were treated with the cable cerclage method.

All participants provided written informed consent to participate in the study, which study was conducted under the principles of the Declaration of Helsinki.

Case report

Case 1

A 41-year-old male patient (G.F.) was transported to the Emergency Room after a snow sledding accident with a suspected foot and ankle sprain. The patient complained of a severe midfoot swallow with plantar ecchymosis and diffuse tenderness, pain on the medial forefoot, and weight-bearing inability. There were any vessel or nerve deficits and passive movements excluded acute compartment syndrome. Initial radiological assessment showed multi-fragmentary fracture of the navicular and a talonavicular dislocation. A

CT was performed to exclude other foot lesions and plan the surgery, which showed a concomitant multi-fragmentary talus fracture and multi-fragmentary cuboid fracture. Navicular fracture was classified as Sangeorzan 3 because of the comminution and the involvement of the talonavicular joint or AO 83Cb. The patient decided to stay at home until the day of the surgery, and was made aware to maintain foot elevation with cyclic cryotherapy and to start antithrombotic prophylaxis with enoxaparin 4000 IU sc/day. Surgery was performed after 10 days when the wrinkle sign was present. The patient was placed supine on a radiolucent table with a femoral tourniquet. Antibiotic prophylaxis with 2 grams of cefazolin was administered. A dorsomedial approach was initially used to reach the talonavicular joint, the incision was between tibialis anterior and tibialis posteriori insertions, and the fragmentation of the fracture prevented an acceptable reduction from this approach, although it was possible to make a temporary TN arthrodesis with a K-wire. After that a dorso-lateral approach was chosen, the incision was over the lateral aspect of the navicular, between extensor hallucis and extensor digitorum longus tendon. This access left a bridge of skin approximately 5 cm wide. During dissection through the subcutaneous tissues, ligation and coagulation of the venous branches of the saphenous vein was performed, while care was taken to preserve the branches of the saphenous and superficial peroneal nerves. A latero-medial screw was inserted through the navicular body to reduce the fracture. The screw used could not prevent radial displacement of all the small fracture fragments, and for this reason a cable cerclage was added. A semi-circular trochanteric cable passer was introduced from the lateral access inferiorly beneath the navicular bone and then out through the medial incision; after that, a 1.8 mm multi-strand Cobalt-Chrome cable (Cable Ready – Cable Grip System – Zimmer) was passed through. The semi-circular trochanteric cable passer was used again and was introduced through the medial incision paying attention to the dorsalis pedis artery and common extensor tendons; the capsule of talonavicular and cuneiform bones was mobilized and lifted off to let the passer in. After that, the cable was passed through completing the circumference. The ends of the cable were then tensioned and sealed using a cable crimp button. Attention was paid to avoid vessel damage and soft tissue irritation from the crimp button.

Post-operative care consisted in foot immobilization in a plaster of Paris for 4 weeks and the patient was kept non-weight bearing. After 4 weeks, the K wire was removed, the immobilization cast was replaced with a walker and passive and active movements of the ankle were allowed. At 8 weeks, radiograph signs of partial healing were present, but initial hypodensity of foot bones was also visibile; partial weight-bearing was started, and full weight bearing was reached at 12 weeks after surgery (Fig. 1).

Figure 1. Case 1 post-operative x-ray 0 and 8 weeks.

Case 2

A 21-year-old male polytrauma patient (V.T.) was transported conscious to the Emergency Room after a motorcycle accident complaining of pain at the lumbosacral area, right foot and ankle and right clavicle. A polytrauma CT scan was performed and revealed a comminuted fracture of the III medio-lateral right clavicle, a minimal fracture of the II right rib with a concomitant right PNX and a depression of the upper endplate of L4 body with retropulsion of the posterior wall into the spinal canal and posterior vertebral body cortex fracture. An X-ray of the foot was also performed and after that a CT scan showed multiple multi-fragmentary fractures of the navicular, cuboid, II and II cuneiform and the base of the II MTT. The navicular fracture was classified as Sangeorzan 3 or AO 83Cb with a concomitant partial Chopart dislocation.

Before orthopedic surgery, a spinal fusion with transpedicular screw, from L3 to L5, was performed to stabilize the L4 fracture. The right foot was swollen and ecchymotic, while the vascular and nervous conditions were acceptable. The surgery was performed after 11 days when the wrinkle sign was present and when the patient was clinically stable.

The same preoperative procedure described above was performed on this patient.

At first a dorsomedial approach was chosen, the incision was between the posterior and anterior tibialis tendons, to initially reduce the fracture a medio-lateral lag screw was inserted through the tuberosity and a second positional screw was placed lateral to medial. The two screws used could not prevent radial displacement of all the small fracture fragments, and for this reason a cable cerclage was added. An accessory lateral access was performed to introduce and pass through the cable wire with the same technique of the previous case.

For treatment of the cuboid fracture, an external fixator in ligamentotaxis fixed in the anterior process of calcaneus and the 4^{th} metatarsal base with two 3 mm pins in each bone was used.

The patient underwent different aftercare management because of the neurosurgical treatment, and wasn't allowed weight bearing for two months. He wore an immobilization cast for one month. After that mobilization of the ankle was allowed without weight bearing. After 2.5 months radiography showed initial reparation signs of the bone, but also initial Sudeck disease as in the other patient; the ROM of the ankle was good and free from pain, the external fixator was removed and the patient was allowed to start partial weight bearing with the help of a walker (Fig. 2).

The data associated with the paper are not publicly available, but are available from the corresponding author on reasonable request.

Discussion

The literature that describes the management of the navicular fractures is still limited, and outcomes are analyzed based on isolated case reports; nonetheless, the technique seems to be still evolving.

Figure 2. Case 2 post-operative x-ray 0 and 8 weeks.

In the past most navicular fractures were treated non-operatively with closed reduction; Main and Jowett reported 29 navicular body fractures, only 3 of which were treated open reduction with fair results [9].

Furthermore, historically, talo-navicular-cuneiform arthrodesis was considered an adequate alternative surgical option [10,11], but nowadays it has been seen that it reduces the hindfoot range of motion, eliminating the subtalar motion and was not well tolerated. It is thus current opinion to avoid it when possible. Primary arthrodesis is still accepted with severely comminuted injuries [7,9] or as a rescue technique in case of persistent pain.

During the past decades, increasingly more studies have reported ORIF as the most widely used technique with better outcomes.

Sangeorzan et al. described 21 navicular body fractures treated with ORIF through a dual approach (anteromedial and lateral) for fractures with lateral comminution; they performed internal fixation with independent lag screws. In that study, the technique was often insufficient to provide adequate stability to maintain reduction during healing and their approach was associated with significant risk to the vascular supply; indeed, in 6 cases avascular necrosis occurred (2 complete, 4 partial) [12].

Richter et al. studied midfoot fractures, and presented 50 navicular fractures pointing out the loss of reduction associated with the K-wire technique, and thus preferring to use screws in order to obtain a better and more stable result [13].

Schildhauer et al. also analyzed complex midfoot fractures, not only navicular, and proposed a temporary internal bridge plating technique to stabilize the medial column from the talar neck to the first metatarsal. In some cases, it was helpful to use K-wire or external fixation to obtain temporary intraoperative reduction, and in others it interfragmentary screw fixation was necessary. The K wires were removed after 6 weeks, and the bridge plate was shortened after 4 months to allow talonavicular joint motion; until then the patient was only allowed to toe-touch weight bearing; after one year all the hardware was completely removed [14].

Apostle et al. described another method of internal fixation using two bridge plates, one third-tubular plate along the plantar-medial aspect from the navicular to the medial cuneiform, and a second one along the dorso-lateral from the navicular to the middle cuneiform; they intended to restore the length of the medial column and prevent collapse without limiting the TN motion [15].

Evans et al. treated 24 navicular body fractures with a mini-fragment plate to restore medial column stability. This technique was performed with an anteromedial or lateral approach, but in 50% of cases both approaches were necessary for adequate visualization of the joint surfaces with a temporary spanning external fixator applied from the calcaneus to the cuneiforms helping to obtain the reduction. Some complications were described: in 4 patients it was necessary to remove the

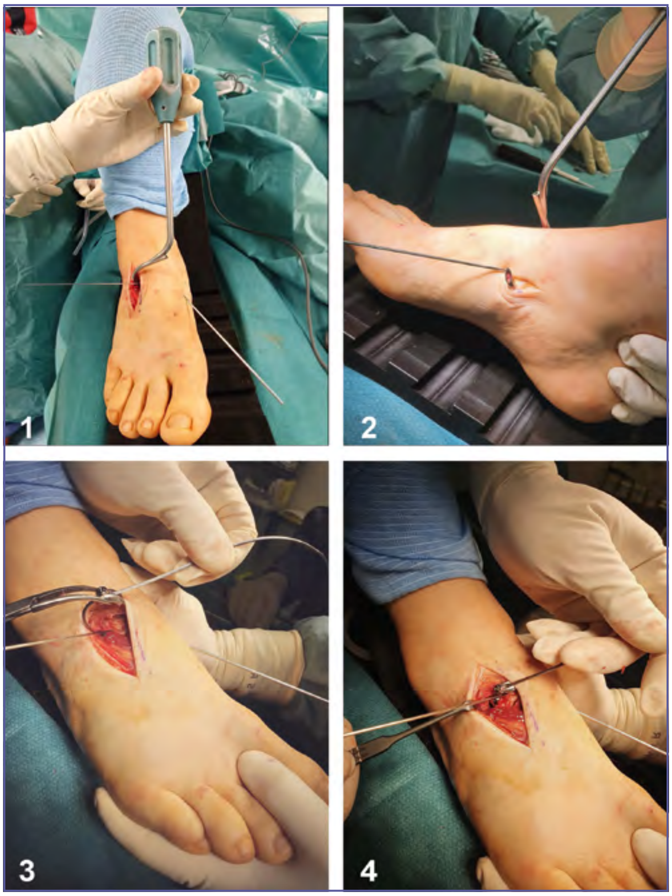

Figure 3. Surgical steps.

plate because of painful prominent hardware, despite the low profile of the mini-fragment plate, in 3 patients broken screws without implant failure were registered, and 4 patients developed arthrosis of the talonavicular joint, even if none had undergone a fusion procedure [16].

Cronier et al. assumed that preoperative planning with 3D reconstruction of CT images (with the suppression of the posterior tarsus) is essential to obtain a better reduction and to prevent unnecessary bone devascularization. The 3D reconstruction helped them to determine that in comminuted navicular body fractures there is consistent presence of a nondisplaced plantar lateral fragment that remains in contact with the cuboid bone and which is of critical importance in obtaining provisional stability with one or more screws as first step of fixation. They presented a series of 10 patients with type 3 navicular body fractures fixed with locking plates; union was obtained in all cases and arthrodesis was not necessary. The plate was slipped under soft tissue to preserve vascularization, and was shaped and cut to the necessary length; they also used a mini-distractor between the head of the talus and one of the cuneiform bones to obtain direct visual control of the reduction; different surgical approaches were used depending on the type of fracture [8].Schmid et al. reported the outcomes of 24 patients with navicular fractures, in these cases surgeons preferred screws to obtain reduction; in comminuted fractures it was necessary to use cancellous bone to fill defects of the navicular body, while n other cases additional K-wires were used to maintain reduction of the talonavicular, calcaneocuboid, or navicularcuneiform joint [17].

Naidu [5] and Singh proposed an alternative technique using a cerclage wire passed through two approaches (dorsomedial and lateral), and used this technique to treat navicular fracture with radially displaced fragments; if the fragments were not reduced, they added screws to fix them. After 14 weeks the hardware was removed [5].

A similar technique was reported later by Kupcha and Freeland in 10 cases; they used a percutaneous access, passing the wire though a circular trochanteric cable passer and, after tensioning it, crimped the wire using a cable blocker. If all the fragments were not secured with the cerclage, the reduction was obtained by adding screws to the K-wire to fix the fragments. The postoperative management consisted in 8 weeks of non-weight-bearing, but follow-up was insufficient to describe if and when the hardware was removed [18].

More recently, Sanders et al. reported 39 cases of navicular fractures treated based on the fracture pattern using circumferential tension band plates or external fixation to restore the length of the medial column, with K-wires, screws or bridge plates as needed, avoiding arthrodesis whenever possible; this was used only when reconstruction of the articular surfaces was not possible, demonstrating that there is not yet a univocal way to manage these fractures [6].

Analyzing the literature and our personal experience, is notable that, even if open reduction and internal fixation is the gold standard for treatment of navicular fractures, there in no consensus about the preferred technique to use in these fractures because the technique chosen is influenced by the surgeon's experience.

Nevertheless, it is possible to find common elements in the postoperative management of these fractures.

Indeed, many authors have indicated that the removal of the hardware used to maintain the alignment (e.g. external fixator, K-Wires, etc.) should be performed after 6 weeks [13,14,17,19].

Immobilization in a cast and non-weight bearing for 6-8 weeks is recommended, and after that progressive weight-bearing is allowed if radiographic evidence of consolidation is seen. Many authors agree to initiate progressive weightbearing after 8-12 weeks [1,4,13,16,18,19].

This was not always possible, such as for the patients described by Schildhauer et al. who were not allowed full weight-bearing until 4 months after surgery when the plate was shortened [14].

Conclusions

Injuries of the navicular are relatively uncommon and this results in less knowledge of their management. The literature describes different surgical techniques for the management of these fractures.

We wanted to present our experience and describe the use of cerclage as a beneficial hardware to fix navicular fractures; in our cases, the cerclage helped to achieve reduction with lag screws preventing radial displacement of the fragments, as demonstrated in other studies [5,18]. We used a trochanteric cable passer to simplify the technique and make it easily reproducible. We also notice that, at the moment, there are no tools or hardware studied specifically for this technique; the hardware used in our patients was not sized for the navicular bone and prevented us from performing a percutaneous approach.

We believe that with adequate tools of smaller size such as a cable passer and with smaller diameter, studied for narrower and more delicate zones, it would be possible to perform a percutaneous approach, so that it could be possible to maintain soft-tissue integrity and prevent avascular necrosis, also to reduce the risk of damaging noble structures during the technique and simplify the technique; furthermore, a smaller cable and cable crimp button could improve the comfort of the patient by considerably decreasing the necessity of future hardware removal. In the end, the use of a cerclage also simplifies the removal of hardware that is expected to be easy and is indicated in case of patient discomfort.

We hope that in the future new tools and hardware can help improve this technique, with the goal of managing navicular fractures in the best way and with the best possible results.

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Conflict of interest statement

The Authors declare no conflict of interest. This study was not submitted to the Institutional Review Board because it is a retrospective study.

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Authors' contributions

All the Authors contributed equally to this work; SG, AA, MM: designed the research; FC: analysed the data; SG, AA, AA: wrote the paper; LB, AR: contributed to manuscript revision; all Authors approved the final version of the manuscript.

Ethical consideration

All procedures in the study and involving humans were implemented in accordance with the ethical standards established by the Helsinki Clarification of 1975 and subsequent amendments. Informed consent was obtained from all patients included in the study.

The article does not contain any studies performed on humans and animals by the Authors.

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