 DOI: 10.55095/achot2024/034

ORIGINAL PAPER/PŮVODNÍ PRÁCE

The Outcomes of Navicular Fracture Surgery

Výsledky operační léčby zlomenin navikulární kosti

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ABSTRACT

PURPOSE OF STUDY

Inadequate treatment of displaced fractures of the navicular bone may result in malalignment, formation of non-union, accelerated development of osteoarthritis or avascular necrosis and thus a fundamental limitation of mobility and gait disturbance. The aim of our study was to evaluate the results in our group of patients undergoing surgery for navicular fractures.

MATERIAL AND METHODS

Our retrospective monocentric study included all surgically treated navicular fractures in patients over 18 years of age performed in our department between 2009 and 2018. A total of 18 patients met these criteria and were invited for clinical and radiographic follow-up. One patient refused to attend and two were lost to follow-up. The remaining 15 patients underwent clinical assessment, including the use of AOFAS midfoot and VAS scores, and the grade of osteoarthritis was determined using radiographs.

RESULTS

Our final group of patients consisted of six women and nine men. The mean age of the patients at the time of surgery was 43 (21–67) years, with mean follow-up duration of 68 (18–130) months. The most common mechanism of trauma was a high-energy injury, occurring in nine of the cases. According to the Schmid classification, six fractures were Type I and II each whereas three cases were Type III fractures. Concomitant injuries involving the foot and ankle were present in six cases. All fractures healed.

Open reduction and internal fixation (ORIF) was performed in 14 cases. The radiographs showed the presence of osteoarthritis grade 0 or I in nine patients and osteoarthritis grades II and III in six patients. The AOFAS Midfoot scale was excellent and good in eleven cases, satisfactory in two and poor also in two cases. The average AOFAS Midfoot scale was 87.7 points. A procedure-related complication was a case of skin necrosis in a patient eventually undergoing cuneonaviculotalar arthrodesis in another hospital.

DISCUSSION

Consistent with literature data, our group showed a higher incidence of concomitant injuries in the foot region. Use of two approaches was not associated with an increased risk of developing avascular necrosis. We do not recommend the use of Kirschner wires for definitive osteosynthesis although we do use them as part of staged treatment or as an additional type of fixation. Like other authors, we observed higher grades of post-traumatic osteoarthritis in the subgroup of patients with more severe injuries.

CONCLUSIONS

Open reduction and stable osteosynthesis of navicular fracture-displacements are associated with good outcomes in most patients. The most serious consequences of these fractures are post-traumatic arthritis and pain. It is critical to search for concomitant injuries. Given the rarity of these fractures, they should be preferably treated in specialised medical centres.

Key words: fracture, tarsal navicular, foot, hindfoot.

INTRODUCTION

Given its shape and location in the foot, the navicular bone plays an important role in movement and transmission of forces during walking; hence, its injury should not be underestimated. Fractures requiring surgery belong to the rarer types of injury. The mechanisms of sustaining a navicular fracture may be both a high-energy injury (as part of polytrauma) and low-energy injury resulting from a foot that is stuck under an object and rotated; importantly, either case can be readily overlooked.

Inadequate treatment of these injuries may result in their healing in malposition, formation of non-union, accelerated development of osteoarthritis (OA) or avascular necrosis (AVN) and thus a fundamental limitation of mobility and gait disturbance (13).

In the past, these fractures were treated mostly by closed reduction and percutaneous osteosynthesis using Kirschner (K) wires or an external fixator. Modern implants have enabled adequate fracture stabilization using a technique called open reduction and internal fixation (ORIF) whose main benefit is the possibility of early rehabilitation.

The aim of our study was to evaluate the results in our group of patients undergoing surgery for navicular fractures.

MATERIAL AND METHODS

A retrospective monocentric study of a group of patients assessed both clinically and using X-ray examination.

Patients and method

Inclusion criteria

Eligible for inclusion in the study were any patients aged at least 18 years undergoing surgery for navicular fracture using either open reduction with internal fixation (ORIF) or closed reduction with internal fixation (CRIF) in the level 1Trauma Center between 2009 and 2018.

Exclusion criteria

Ineligible for the study were patients suffering pathologic or stress fractures.

A total of 18 patients met the above criteria and were invited by telephone for clinical assessment and radiographic examination. One patient refused to attend a follow-up visit and two patients were unavailable. The final group consisted of 15 patients with 15 fractures.

Data analysis

Patients' hospital records were used to obtain information on their sex and age, mechanism of injury, associated foot and ankle injuries, presence of combined injuries (impairment of at least two organ systems that do not threaten the patient's life) or polytrauma, time between injury to surgery, type of surgery and the osteosynthetic material used. All patients had preoperative CT scans with 2D image reconstruction in 3 standard planes to be classified using the system proposed by Schmid et al. (21) as follows: Type I – 2-part fractures, Type II – comminuted fractures and Type III – fractures with talonavicular joint dislocation and/or concomitant talar head fractures.

The actual clinical assessment consisted of completing the American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot scale questionnaire (100–91 points, excellent; 90–81 points, good; 80–71 points, satisfactory; and 70 points and less, poor outcome), and recording pain intensity using the visual analogue scale (VAS) with a range of 0–10 (0, no pain; 10, maximum pain). Radiographs obtained in the anteroposterior, medial oblique and lateral projections were used to assess the presence of OA involving the talonavicular and naviculocuneiform joints. The assessment of OA was performed using the following classification: grade 0, normal or subchondral sclerosis; grade I, presence of osteophytes without joint space narrowing; grade II, joint space narrowing with/without osteophytes; grade III, almost complete or complete disappearance of the joint space or its deformation.

Statistical methodology and approaches

As the number of patients in the study is relatively small, asymptotic statistical methods based on the maximum likelihood techniques are not appropriate. In order to investigate relationships among several discrete characteristics represented by the factor variables (results of AOFAS Midfoot Scale of patients, AOFAS Midfoot Scale vs type of fracture), the Freeman-Halton extension of the Fisher exact probability test for inspecting relationship between two categorical variables is utilized. The theoretical significance test level was set at 0.05. The R statistical software (version 4.3.2) was used for calculations.

Surgical procedure and postoperative care

Indications for surgery were based on general recommendations available in the relevant literature including fragment displacement ≥ 2 mm, medial column shortening > 3 mm, inability to retain the bone fragments in their correct position in the joint, open fractures, compartment syndrome or pressure put by bone fragments on the skin. (7, 10, 14, 18)

Based on the pattern of the fracture, either open reduction and internal fixation (ORIF) or closed reduction and internal fixation (CRIF) were performed. A tourniquet was placed in all cases; however, it was pulled tight in most cases only for the time necessary to reduce the fracture if using the open reduction technique (ORIF).

While, with the dorsal approach, the incision was made medially from the tendon of the *m. extensor hallucis longus*, when 2 incisions were necessary (dorsal and medial approach), the

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incision was made laterally from the *m. extensor hallucis longus* tendon, along the axis of the 2nd metatarsal, to ensure the formation of an adequate skin bridge. Upon cutting through the thin subcutaneous tissue while protecting the cutaneous nerves, the thicker fascia (inferomedial oblique band of the inferior extensor retinaculum) was transected to identify, by palpation, the neurovascular bundle, which was subsequently gently pulled away; after that, the individual fragments of the navicular bone were gradually released.

The medial approach (under fluoroscopic guidance) was targeted to access the center of the medial side of the navicular or, possibly, somewhat lower depending on the pattern of fracture lines to obtain a sufficient skin bridge (when 2 approaches were needed); alternatively, the approach was determined by palpating the navicular tuberosity. Following a horizontal skin incision and cutting through the subcutaneous tissue, fracture fragments were gently released from the ligaments. To visualize the talonavicular joint, it was necessary to transect the *ligamentum tibionaviculare*. The attachment of the *m. tibialis posterior* tendon to the navicular bone is for the most part from the plantar side, therefore it does not interfere with the osteosynthetic material itself. When using 2 approaches (dorsal and medial), the skin bridge was undermined together with the *m. tibialis anterior* tendon. A distractor has been used to allow the surgeon to control the reduction of fragments in comminuted fractures (3,7,17).

Fixation was done with screws (sizes 2.0–3.5 mm), locking compression plates for navicular bone (LCPs)(DePuy Synthes, Raynham, Massachusetts, USA), Kirschner wires or a combination of screws with an external fixator.

All surgical wounds were primarily sutured, and patients had a rigid brace placed; in the patient with an external fixator applied, a below-knee cast was used for additional fixation, as did the patient with K-wire fixation only.

Postoperative care was set according to the type of osteosynthesis and associated foot and ankle injuries. Patients treated with stable osteosynthesis started rehabilitation upon postoperative pain subsidence while avoiding weight-bearing of the operated leg, between rehabilitation visits the leg was in a brace. In the presence of concomitant injuries, relatively stable osteosynthesis or Type III injury, the foot was fixed in a rigid brace or plaster cast for 6 weeks with rehabilitation commencing thereafter. Gradual weight-bearing of the affected limb was started at 6–8 weeks postoperatively depending on the type of injury.

Outpatient follow-up visits were scheduled at intervals of 6 weeks, 3 months and one year postoperatively. The visits included assessment of the foot radiographs and range of movement, together with designing a further rehabilitation plan in terms of limb loading and physical therapy tailored to meet individual patient needs.

RESULTS

Patients and fractures

Our group of patients included six women and nine men, with a mean age of 43 years (21–67) at the time of surgery. The average time between surgery and clinical assessment was 68 months (18–130).

The mechanism of injury was high-energy trauma in nine cases including falls from a height in four; road accidents in three and falls while downhill mountain biking in two cases. In five cases, the injury involved low-energy trauma ranging from uncomplicated ankle sprain to foot stuck under an obstacle. In one case, the mechanism of injury was not identified.

Using the classification system proposed by Schmid et al., six fractures were Type I, six Type II and three Type III.

Concomitant injuries involving the foot and ankle regions – mostly calcaneus and metatarsal fractures – occurred in six cases. In two patients, the navicular fracture was part of a combined injury (one patient had fracture of the lumbar vertebra and second patient had fracture of the lumbar vertebra, ribs and contusion of the lungs).

Surgical outcomes

All fractures, fifteen out of fifteen healed.

Two patients had definitive surgery within 24 hours. The remaining thirteen patients had delayed surgery, with the time between injury to surgery being an average of 9.5 days (6–13). In one case, Chopart's fracture-dislocation was associated with pressure of fragments on the skin; hence, the patient had primary stabilization with K wires (due to poor condition of the soft tissues, the wires were left in place as definitive fixation).

Open reduction and internal fixation (ORIF) was performed in fourteen cases whereas closed reduction and internal fixation (CRIF) in one patient.

The use of the ORIF technique was most associated with one approach, in nine out of fourteen cases, while a combination of two approaches was opted for in the remaining five.

Screw fixation was used in eleven cases (sizes 2.0–3.5 mm) Fig 1., of which a combination of screws with an external fixator was used in one. In three cases, LCPs to the navicular bone were used (DePuy Synthes, Raynham, Massachusetts, USA) Fig 2., and K wires employed in one case.

Spongioplasty of the navicular bone was not performed, only in one case it was performed to support the impression of the head of the talus.

Grade 0 or I OA was documented in the radiographs of nine patients, and grades II and III OA in six patients, including the one undergoing cuneonaviculotalar arthrodesis.

The AOFAS Midfoot Scale was excellent in six cases, good in six and satisfactory in two and poor in one case including

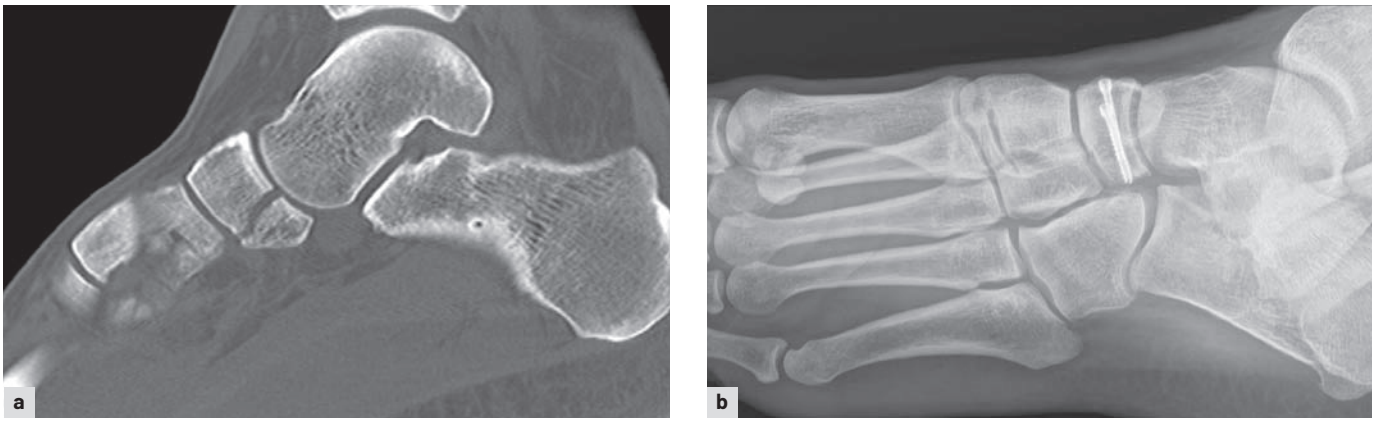

Fig. 1. **a – CT of fracture of navicular bone; b – X-ray 5 years after osteosynthesis using 3.0-mm headless compression screws.**

Figs 2. **a, b – trauma CT; c, d – CT after osteosynthesis by plate; e, f – X-ray 5 years after osteosynthesis.**

the patient with cuneonaviculotalar arthrodesis. The average AOFAS Midfoot scale was 87.7 points.

Pain severity below 3 according to the VAS score was reported by eight patients including the patient with cuneonaviculotalar arthrodesis.

An early procedure-related complication was wound edge necrosis in one case, which healed with repeated dressing changes.

The K wires used either for definitive or additional fixation (three cases), were extracted on an outpatient clinic at 6 weeks postop, as was the external fixator.

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One patient underwent cuneonaviculotalar arthrodesis in another hospital (at 3 years post-injury) for osteoarthritis in the respective joints.

Results are summarized in Tabel.

Results of the statistical analysis

The pairwise associations between the observed patients' characteristics were statistically evaluated. The exact Freeman-Halton-Fisher test revealed that there are significant relationships between the pain and the footwear requirement (P-value = 0.029), the activity limitations and the walking surfaces (P = 0.011), and between the footwear requirement and the walking surfaces (P = 0.029). However, the remaining pairwise associations become statistically non-significant (i.e., P-value > 0.05) bearing in mind the sample size. For instance, there are insignificant relations between the type of fracture and the pain (P = 0.688), the type of fracture and the activity limitations (P = 0.433), the type of fracture and the footwear requirement (P = 0.999), or between the type of fracture and the walking surfaces (P = 0.890).

Table 1. **Summary of results**

	PATIENT (sex/ age, years)	FOLLOW-UP (months)	MECHANISM OF INJURY	FRACTURE TYPE	TECHNIQUE/OS TYPE /NUMBER OF APPROACHES	CONCO-MITANT INJURIES	AOFAS SCALE	OSTEOARTHROSIS GRADE (TN/CN joint)	VAS SCORE
1	F/27	18	Fall from motorcycle	II	ORIF/plate//2	MTT fracture	100	0/I	1–2
2	M/21	21	Road accident	II	ORIF/plate/2	–	90	I/I	1
3	F/68	29	Fall from chair	II	ORIF/plate/1	Talar + calcaneus fracture	70	II/I	5
4	M/49	41	Road accident	III	ORIF/screws + transfixation with K wire/2	–	82	II/II	5
5	M/41	43	Foot stuck under car	I	ORIF/screws/1	–	90	I/0	4
6	F/41	58	Talar distortion	I	CRIF/HCSs	–	100	0/0	2
7	F/67	66	Fall from chair	I	ORIF/screws/1	–	87	II/I	4
8	M/32	67	Fall from scaffolding	II	ORIF/screws + Ex-Fix/1	–	100	I/I	0
9	M/37	68	Fall from bicycle	III	ORIF/screws + K wires/2	Talar head impression	100	II/I	0
10	M/37	80	Jump from window	III	ORIF/K wires/1	Calcaneus fracture	77	Cuneonaviculotalar arthrodesis	4
11	F/53	80	Fall from rock	I	ORIF/screws/1	Calcaneus fracture	62	I/0	5–6
12	M/51	81	Fall from trailer	II	ORIF/screws/2	–	93	I/I	2–3
13	M/30	92	Fall from bicycle	II	ORIF/ screws/2	–	100	0/0	0
14	F/54	127	–	I	ORIF/screws/1	–	90	I/0	2–3
15	M/43	130	Fall from ladder	III	ORIF/screws/1	Lisfranc joint lesion + MTT + cuboid + PPT	75	II/III	4

F – female, M – male, OS – osteosynthesis, ORIF – open reduction and internal fixation, CRIF – closed reduction and internal fixation, LCP – locking compression plate, HCS – headless compression screw, Ex-Fix – External fixateur, K – Kirschner, MTT – metatarsal bone(s), PPT – *processus posterior tali*, TN – talonavicular, CN – cuneonavicular, VAS – visual analogous scale.

DISCUSSION

Concomitant injuries

The talonavicular joint is part of Chopart joint and with calcaneocuboid joint play very important role in foot function. Impairment to one of these joints can lead to affection of whole foot (15). Another joint which is closely related with talonavicular is the subtalar joint (8,12). In fact, talonavicular fusion will virtually preclude movement in the subtalar joint, whereas subtalar arthrodesis will restrict the range of movement of the talonavicular joint to a mere 26% on average. Therefore, any concomitant injury associated with navicular fracture may more seriously limit a patient's mobility and eventually produce a worse outcome. Authors reporting concomitant injuries in navicular fracture suggest an incidence of 54–62% (5,9,19).

40% of our patients presented with concomitant foot injuries, even with Type I injuries according Schmid classification. Two patients sustained a navicular fracture as part of a combined injury. We didn't record polytrauma. Four out of 15 patients had type III according to Schmid classification, which indicates an injury to the Chopart joint as a whole. It follows from this that one must search for additional foot injuries adversely affecting the outcome, especially if they are overlooked.

Approaches and avascular necrosis

Only 58.8% of navicular bones have diffuse intraosseous blood supply (11). Use of two approaches with the ORIF technique may entail further damage to the vascular supply of an already damaged bone thus increasing the chances of developing avascular necrosis (AVN). Cronier (5) used two approaches, in five out of 10 cases and reported one case of partial necrosis; this, however, occurred in a single-approach patient. Evans (9) used two approaches in 12 out of 24 cases, with AVN occurring in one patient left with a fracture-dislocation in the talonavicular joint untreated for three weeks.

In our group of patients, two approaches were employed when managing Type II and III fractures in five out of the nine patients, with zero cases of AVN. As our results and experience of other authors suggest no substantial increase in the risk of navicular AVN, we continue using two approaches as they allow better visualization and fragment reduction if necessary.

Type of fixation

In general, the relevant literature recommends the use of K wires, either as part of a temporary fixation prior to the definitive procedure or as an additional fixation method for fracture-dislocation before commencing to a more stable osteosynthesis (2,3,7,13,16,22). In our group of patients, K wires alone were used in one case for fracture fixation in a procedure originally planned as a two stage; however, because of the poor condition of soft tissue, the K wires were left in place as definitive fixation. During the healing process, the fragments became slightly displaced, the fracture did heal but with subsequent early development of OA, which required, within a period of 3 years, cuneonavicular arthrodesis performed in another center. This explains why we do not use K wires for definitive fixation.

Another therapeutic option is the combination of implants of various stability such as screws and external fixators. Diab (6) reported excellent results using screws in combination with an external fixator, however, without identifying fracture types. This option is also recommended by other authors, but only in comminuted fractures or as an additional fixation to a stable type of osteosynthesis (4,7,14,18). In our group of patients, this technique has been used in one patient, with good results, because of a comminution zone in the lateral part of the bone to prevent bone collapse. We reserve the use of an external fixator as a relative type of osteosynthesis in definitive treatment as an ultimum refugium in the management of comminuted fractures of the navicular bone with the impossibility of performing absolute stability, which we prefer.

Osteoarthrosis

Development of OA poses one of the main challenges following navicular bone injury. Sanders et al. (19) reported the presence of talonavicular OA in Type III fractures in 14 out of 21 cases, with four patients in this group undergoing immediate primary talonavicular arthrodesis for non-reconstructable damage to the joint surfaces. In Coulibary's group of patients (4), OA was diagnosed in 35 out of 41 patients with surgically treated fractures and in 21 out of 49 patients with fractures not managed by surgery. By contrast, in their group of patients, Evans et al. (9) documented talonavicular OA in only four out of 30 patients. All these patients had Type III fractures according to the Sangeorzan classification (20) (Sangeorzan classification – Type I – fracture occurs in the coronal plane and typically involves the dorsal and distal aspects of the bone without forefoot malalignment. Type II fracture extends from dorsolateral to plantarmedial and often involves displacement of the forefoot. Type III fracture is a comminuted fracture of the body of the navicular and often involves lateral displacement of the forefoot). While none of their patients had talonavicular arthrodesis, the author did not rule out the procedure would not be performed at some point in the future. Schmid et al. reported grade III and IV OA by Kellgren-Lawrence's classification in seven out of 22 patients (21). Based on their results, the two later authors prefer ORIF to primary arthrodesis.

Grade 0 or I OA involving the talonavicular or naviculocuneiform joint was diagnosed in nine out of the 15 of our patients.

Among nine patients with more than 5 years after surgery, grade 0 or I OA was present in five (55%). While higher-grade OA (grades II and III) was present mostly in patients with Type III injury (four cases), three of these patients (including one that undergoing talonavicular arthrodesis) had sustained the injury more than 5 years ago. Hence, post traumatic OA seems to be most likely to develop in the group suffering the most serious fracture type according to Schmid, i.e., with dislocation fractures in Chopart's joint. However, in view of the results reported for this type of fracture, we are in favour of osteosynthesis or temporary bridging of the fracture with a plate as first-line treatment. Osteosynthesis enables the patient to function, for some time, in a way as close as possible to that prior to injury until, e.g., limited arthrodesis is undertaken, a strategy recommended, also by Rammelt et al. (16) and Sanders et al. (19); primary arthrodesis should be reserved for non-reconstructable damage to the articular surface.

AOFAS scale and VAS

The AOFAS Midfoot scale was included in the follow-up examination as a measure of the overall foot health status. Schmid et al. (21) reported an average AOFAS scale of 83.8 points during a mean follow-up of 73 months. Cronier et al. (5) described an average AOFAS scale of 90.6 points over a mean follow-up period of 20.5 months; their study enrolled only patients with Type II and III injuries according to the Sangeorzan classification (20), outcomes comparable with those obtained during longer follow-up of a heterogeneous group of fractures in the study by Schmid et al. (21).

In our group of patients, excellent and good outcomes were obtained in 11 out of 15 cases (including the talonavicular arthrodesis patient to give a general idea about patients suffering a navicular fracture). During a mean follow-up of 68 months, the average AOFAS scale in our group was 87.7 points, a result comparable with those of the above authors; needless to say, a longer follow-up is warranted. According to the statistical analysis of the results of the AOFAS Midfoot Scale, pain affects the choice of footwear, the limitation of daily activities and walking on uneven surfaces, which correlates with reality, when pain clearly affects our movement. At the same time, no clear relationship was found between the type of fracture (its severity) and pain, choice of footwear and walking on uneven surfaces. However, this may be biased by the small number of patients.

The VAS score reflects mainly a patient's subjective perception of pain severity making the score, by implication, subject to substantial bias. Despite this, a correlation can be found between the VAS score and the radiological finding or AOFAS scale. In our study group, a VAS score below 3 was present in eight patients while a score over 3 was documented in seven patients, of which five patients had concomitant foot injuries or Type III fracture. One patient suffered an occupational accident, while another one was diagnosed with grade II OA in the talonavicular joint. In our view, the VAS score can be used to give a more detailed idea of the consequences of these fractures.

CONCLUSIONS

Open reduction and stable osteosynthesis of displaced navicular fractures are associated with good outcomes in most patients. The most serious consequences of these fractures are posttraumatic osteoarthritis and pain. It is important to search for concomitant injuries. Given the rarity of the injury, it is appropriate to manage these fractures in specialised medical centers. ■

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