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1 Fractures of the navicular

1.1 Surgical anatomy

The navicular is part of the Chopart’s joint, which is composed of the articular surfaces of the talar head and navicular medially and of the distal calcaneus and cuboid laterally. Biomechanically, it is part of the medial arch of the foot and has five articulations:
- the talar head proximally (talonavicular joint);
- the three cuneiforms distally (innominate joint);
- the cuboid laterally (cubonavicular joint).

The medial and plantar aspects of the navicular are supported by soft tissues including the plantar calcaneonavicular ligament (spring ligament), the medial calcaneonavicular ligament (ligamentum neglectum), and especially by the insertion of the strongest of the five arms of the tibialis posterior tendon. Laterally it is supported by the lateral calcaneonavicular ligament and the dorsal cubonavicular ligament. The dorsal joint capsule is reinforced by the dorsal talonavicular ligament, parts of the deltoid ligament, and the “neglected” ligament. The quadrilateral part of the navicular is stabilized by the navicular arm of the bifurcate ligament and the cubolateral navicular ligament. Pathomechanically, the tibialis posterior tendon may avulse the tuberosity in eversion trauma, or it can become entrapped in fracture dislocations making reduction difficult. Because of its central position in the foot, injuries to the navicular are often associated with injuries to the rest of the Chopart joint and/or Lisfranc joint. These must be excluded by clinical and x-ray examination and CT scan.

1.2 Fracture patterns and treatment

There are three types of injury: cortical avulsions, fractures of the tuberosity, and fractures of the body [1]. Stress fractures are occasionally seen in athletes.

Cortical avulsion fractures are the result of a twisting injury rupturing the strong talonavicular capsule and the most anterior fibers of the deltoid ligament; a bone fragment is avulsed. Treatment consists of a short leg walking cast for 6 weeks. If the fragment includes more than 20% of the articular surface, or if there is significant instability seen on a stress-x-ray (Fig 6.10.2-1a–c), it should be stabilized with small screws (Fig 6.10.2-1d–f).

Tuberosity fractures are caused by an eversion injury, with the tibialis posterior tendon pulled off the navicular tuberosity. If seen together with a crush fracture of the cuboid, this injury may indicate an occult dislocation or subluxation of the midtarsal joint. Without displacement, a short leg walking cast for 6 weeks is the appropriate treatment. With displacement (> 2 mm), the fracture is reduced and stabilized with a screw or small tension band wire (Fig 6.10.2-2).

Body fractures are usually associated with other midtarsal injuries, which must be diagnosed and treated. Only nondisplaced fractures are treated using a well molded short leg cast for 6 weeks.

- Displaced fractures of the navicular are treated operatively with screws, a plate, or a small temporary external fixator.

Bone defects in case of crush fractures should be filled with an autograft (Fig 6.10.2-3).

Stress fractures usually need compression by two or three 4.0 mm cancellous bone screws and a short leg walking cast for 6 weeks (Fig 6.10.2-4).
Fig 6.10.2-1a–f  Avulsion fracture of the navicular.
a–c  Cortical avulsion fracture of the navicular with significant instability.
d–f  The large intraarticular fragment was fixed with three 2.0 mm cortex screws. K-wires have been used to stabilize the Chopart joint and the fixation was protected with an external fixator.
Fig 6.10.2-2a–c  Navicular tuberosity fracture.
  a  A navicular tuberosity fracture as part of a complex triple fracture of the Chopart joint.
  b–c Lag screw fixation of the navicular at 5 months (b) and 1 year (c).

Fig 6.10.2-3a–d  Complex navicular fracture.
  a  A multifragmentary navicular body fracture.
  b  ORIF with plating of the 3-part body fracture and tension band wiring of the tuberosity fracture.
  c–d Final fixation.

Fig 6.10.2-4  Lag screw fixation of a navicular stress fracture.
2 Fractures of the cuboid

2.1 Surgical anatomy

The cuboid is the lateral of the two midfoot bones and is an essential bone of the lateral column of the foot. It articulates
- proximally with the calcaneus (calcaneocuboidal joint);
- medially with the navicular (cubonavicular joint);
- medially with the lateral cuneiform (cubocuneiform joint);
- distally with the bases of the fourth and fifth metatarsal (cubometatarsal joint).

2.2 Fracture patterns and treatment

The most common significant injury to the cuboid bone occurs as a result of the “nutcracker” mechanism described by Hermel and Gershon-Cohen [2]: In abduction injuries, the cuboid is crushed between the calcaneus and metatarsals. This is comparable to the “nutcracker” fracture of the navicular in forced adduction injuries [3].

If there is minimal impaction, nonoperative management with a below-knee cast for 6 weeks is appropriate. However, if there is significant loss of length or abduction malalignment of the lateral column of the foot, it is likely that the long-term outcome will be pain and dysfunction in the calcaneocuboid joint and/or involvement of the fibularis longus tendon. Management should include early anatomical reconstruction of the joint surfaces proximally (Fig 6.10.2-5) and/or distally as well as restoration of the length of the lateral column by ORIF.

In compression fractures of the cuboid bone, the intact joint surface of the calcaneus proximally or those of the fourth and fifth metatarsal base are considered for use as a mold. Using a little distractor for reduction, filling the defects with bone graft, and placing a locked plate on the lateral cuboid protects anatomical reconstruction of the joint and effectively restores the lateral column length.

3 Tarsometatarsal joint injuries

3.1 Surgical anatomy

The Lisfranc area, which describes the transition between the forefoot and midfoot, is formed by the articulations of the metatarsals with the cuneiforms and the cuboid. Proper alignment and stability of this group of joints is crucial for normal foot function.

The medial column of the midfoot includes the three cuneiforms and the medial three metatarsals. This column is less mobile than the lateral column and rather serves as a structural support.

- The inherent stability of the tarsometatarsal joint is due to the bone anatomy of the keystone-like base of the second metatarsal, and to the strong ligaments between each tarsometatarsal joint.

Generally, plantar ligaments are stronger, and the Lisfranc ligament is the largest and strongest of all. It originates from the plantar aspect of the medial cuneiform and inserts on the plantar aspect of the base of the second metatarsal and is the only link between the first and second metatarsal. The Lisfranc ligament “locks” the base of the second metatarsal in place, further limiting motion and providing stability to this keystone structure.

The lateral column, made up of the cuboid and the lateral two metatarsals, is more mobile than the medial column in order
6.10.2 Midfoot and forefoot

Fig 6.10.2-5a–g Fracture of the cuboid.
a–d Impaction fracture of the cuboid with abduction malalignment of the lateral column.
e–g Cuboid plate fixation and bone graft at the 3-month follow-up.
6 Specific fractures
6.10 Foot

to allow walking on uneven ground. This flexibility is necessary for proper foot function. Posttraumatic instability is better tolerated here, but stiffness causes significant problems.

In reconstructing the tarsometatarsal joint, it is critical to keep these anatomical characteristics in mind. Perfect anatomical reduction is crucial for excellent long-term results [4, 5].

3.2 Fracture patterns and assessment

Injuries to the midfoot affecting the tarsometatarsal or Lisfranc joints can be difficult to diagnose and treat. These injuries encompass a wide spectrum, from simple sprains to grossly unstable dislocations. They cause severe long-term morbidity if not appropriately treated. Up to 20% of such injuries go unrecognized as many appear to reduce spontaneously, although on closer examination they remain displaced. As a result, many patients are sent home with a diagnosis of foot sprain.

Untreated Lisfranc injuries have a poor outcome. Thus, any traumatic mechanism with significant midfoot pain or swelling should arouse suspicion of a possible Lisfranc injury.

Clinically, these injuries are painful during palpation over the tarsometatarsal joint. There is often dorsal midfoot swelling along with medial plantar bruising. If the patient is able to stand, he/she may have pain with single limb heel rises. Compartment syndrome is possible in cases with significant swelling.

If possible, standard weight bearing x-rays of the foot should be obtained (AP, lateral, and 30° internal oblique views). Stress views help to reveal displacement in cases of spontaneous reduction; however, they are painful and should be done under an anesthetic block or sedation. One should look for deviations of normal alignment between each metatarsal base and its opposing tarsal bone. Any displacement > 2 mm on standard or stress views means instability. The AP view is best suited for evaluating lateral displacement of the second metatarsal on the intermediate cuneiform. The lateral border of the first cuneiform should line up with the first metatarsal base. The lateral view helps to assess any dorsal displacement. The oblique view is optimal for assessing alignment of the third and fourth metatarsals with the lateral cuneiform and cuboid, respectively. The most significant indicators of instability are the positions of the second and fourth metatarsals (Fig 6.10.2-6).

Advanced imaging techniques, such as CT or MRI, demonstrate the 3-D anatomy of the tarsometatarsal joint complex and may be helpful in assessing associated injuries, such as fractures at the metatarsal bases.

Lisfranc injuries are classified according to subsequent instability patterns [6–8]:

- homolateral (medial or lateral);
- divergent (partial or complete) (Fig 6.10.2-7).

As yet no system exists to aid in determining treatment or predicting outcome.

3.3 Preoperative planning

Initial management of Lisfranc injuries centers on the soft tissues. Elevation of the foot to heart level (not higher) helps to decrease swelling, while avoiding potential lack of circulation to the injured extremity (pressure head effect). Close monitoring for compartment syndrome is advised. The use of the foot pump has been shown to speed up resolution of swelling but is controversial especially in light of possible compartment syndrome.

Stable injuries may occur as the result of seemingly innocuous accidents, such as stumbling off of a curb. Stable injuries may be treated nonoperatively with immobilization in a short leg
6.10.2 Midfoot and forefoot

Fig 6.10.2-6a–d
a An AP x-ray that demonstrates a loss of normal relationship between the second metatarsal and the intermediate cuneiform.
b–c Oblique x-rays that show a normal left (b) and an injured right foot (c) with abnormal relationship of the third and fourth metatarsal to the lateral cuneiform and cuboid.
d A lateral x-ray that shows dorsal displacement of the first metatarsal in relation to the cuneiform.

Fig 6.10.2-7a–c Descriptive classification of tarsometatarsal injuries.
a Divergent (complete).
b Medial divergent (incomplete).
c Complete lateral divergent.
Specific fractures

Foot

Cast (with the forefoot adducted), followed by a postoperative boot, with progressive weight bearing as tolerated after 8 weeks. Usually, full weight bearing should be delayed for 3 months. At 3 months, if free of pain, the patient may fully bear weight and begin rehabilitation. A cushioned insert with medial posting is used to support the arch.

- **Any Lisfranc joint with a displacement of > 2 mm compared to normal joint position on plain, stress, or weight-bearing x-rays is considered unstable, and operative treatment is indicated.**

It is imperative to treat these injuries early and aggressively. Emergency treatment includes closed reduction and splinting to protect the soft tissues. Reduction is often difficult due to capsule interposition, avulsion fragments, joint surface impaction, or interposition of the tendon of the tibialis anterior in the first interspace.

The timing of surgery and the placement of the incision are determined by the soft tissues. Subtle injuries with minimal swelling should be treated almost immediately. Acute dislocations should be reduced within 4–6 hours as circulation to the forefoot can be compromised. Significant soft-tissue injury necessarily delays operative treatment, the exception being compartment syndrome, where the definitive treatment may occur at the same time as the decompression. Good imaging of both the injured foot and the contralateral foot is helpful for proper planning.

### 3.4 Operative treatment

Although there is regional variation in approaches, the double-incision dorsal approach is preferred because it allows excellent inspection and reduction. The incisions are centered over the first and fourth metatarsal and the tarsometatarsal joints, and dissection continues straight down without undermining. This protects the neurovascular bundle and soft tissues between the two incisions. Once at the periosteum, medial and lateral dissection is allowed. The first tarsometatarsal joint and the medial half of the second tarsometatarsal joint are approached through the medial incision. The lateral half of the second tarsometatarsal joint and the third tarsometatarsal joint are approached through the lateral incision. The fourth and fifth tarsometatarsal joints usually reduce with the medial metatarsals. After incision and exposure, the joint surfaces must be freed of debris, capsular interposition, and any impediments to reduction.

Screws should be solid with a low profile head and a large shaft. The 3.5 mm cortex screw is preferred around the midfoot. Cannulated screws should not be used in this area as they do not have sufficient strength to resist the forces here. Screw heads must be countersunk to prevent dorsal cortical breakout as the head engages (Fig 6.10.2-8). The base of the second metatarsal is reduced into its keystone position and a lag screw is placed from the medial cuneiform through the base of the second metatarsal. The first tarsometatarsal joint is then reduced from the dorsal first metatarsal base to the medial cuneiform using a lag screw. If a second screw is needed, it is placed from the dorsal medial cuneiform to the plantar aspect of the first metatarsal. The third tarsometatarsal joint is then reduced and stabilized with a lag screw from the third metatarsal into the intermediate or lateral cuneiform (Fig 6.10.2-9). Each of these joints should be provisionally fixed with 1.6 mm K-wires before the screws are placed. The position should be checked with the image intensifier. The lateral column is stabilized using indirect reduction and percutaneous fixation with K-wires.

If primary fusion of the first three tarsometatarsal joints is desired (as in the case of purely ligamentous injuries), the articular cartilage should be appropriately removed and a bone graft should be placed. In late cases, a pes equinus contracture...
is often present. An Achilles tendon lengthening should be performed at the time of initial surgery as it is believed that a coexisting pes equinus contracture causes undue stress across the midfoot. This can contribute to late failure and joint arthritis. Some advocate reduction and fixation of small fragments at the metatarsal bases before definitive ORIF is performed. This can be helpful in very unstable injury patterns.

**Fig 6.10.2-8a–b** Lateral (a) and AP (b) view of the first metatarsal. A dorsal notch in the metatarsal shaft will prevent the dorsal cortex from splitting on screw insertion and will reduce the prominence of the screw head. The drill hole should be placed in the top of the notch.

**Fig 6.10.2-9a–d** Reduction and fixation of a Lisfranc injury. 
- **a** Reduction and initial screw placement.
- **b–c** Medial column fixation.
- **d** Lateral column fixation with K-wires.
3.5 Postoperative treatment

A short leg splint is used to initially immobilize the injured foot. 2 weeks after surgery the splint is exchanged for a cast or postoperative boot. Weight bearing progresses as tolerated after approximately 8 weeks. Full weight bearing is not allowed until 3 months postoperatively. Patients may ambulate without cast/brace when they can do so painlessly. A medial, cushioned arch support should be used to protect the foot. Lateral column K-wires should be removed at 6–8 weeks. First, second, and third tarsometatarsal joint screws may stay in permanently unless symptomatic. However, they should remain in place for a minimum of 6 months. Hardware removal is practiced differently by many surgeons and is not required routinely.

3.6 Results

A direct correlation has been found between anatomical reduction and good x-ray or clinical outcomes [4, 5]. Poorer outcomes have been noted for purely ligamentous injuries [9]. For these reasons, many surgeons choose to primarily fuse the injured joints. If a pes equinus contracture is present, an Achilles tendon lengthening should be performed at the time of definitive surgery for this injury.

4 Metatarsal fractures

4.1 Principles

The aim of reconstruction after fractures is the functional alignment of the metatarsal heads with functional mobility of the metatarsophalangeal joints. In this respect, active flexion of the metatarsophalangeal joints is essential for painless gait. Correct alignment of the metatarsal heads must include alignment in the horizontal plane as well as in the sagittal plane. The latter also depends upon mobility of the corresponding tarsometatarsal joint. Consequently, individual shortening or angulation of the metatarsal must be avoided.

4.2 Treatment

4.2.1 Single-ray fractures

The majority of fractures are localized on the first and fifth ray. If the local soft tissues do allow open reduction, fixation with screws, or with plate and screws permits immediate, functional, postoperative treatment with partial weight bearing. The first ray is best fixed with a plate 2.7 or 2.4. The fifth ray can be treated nonoperatively, if nondisplaced, or operatively, if displaced. If displaced, the fifth ray is best fixed using a plate 2.0 and/or 2.0 mm screws (Fig 6.10.2-10).

4.2.2 Multiple-ray fractures

In cases of multiple fractures situated proximal to the metatarsal heads, the intermetatarsal ligament (first ray excepted) has an important role in stabilization. If the fractures are transverse, the metatarsals do not tend to shorten due to shear. Fixation by means of multiple intramedullary K-wires may be very efficient. The wires must be inserted through the plantar side of the phalanx, thus transfixing and holding the corresponding metatarsophalangeal joint in an anatomical position (Fig 6.10.2-11; 6.10.2-12).
6.10.2 Midfoot and forefoot

**Fig 6.10.2-10a–b**  Fifth metatarsal fracture treated with 2.0 mm lag screws.

**Fig 6.10.2-11a–b**  Metatarsal alignment with K-wires to prevent dorsal displacement or angulation of the distal fragment. The wire must transfix the metatarsophalangeal joint to allow correct alignment of the metatarsal.

**Fig 6.10.2-12**  Second to fifth metatarsal fractures fixed with K-wires.
4.2.3 **Unstable and intraarticular fractures**

In oblique distal fractures, axial shortening is likely. In these cases as well as in all other cases with an obvious risk of axial shortening or angulation, open plate and screw fixation must be considered (Fig 6.10.2-13). The approaches can be linked for the second and third rays (intermetatarsal longitudinal approach). The fourth and fifth metatarsals can be fixed through the respective intermetatarsal dorsal approach as well. We do not advocate transverse approaches. The first and isolated fifth metatarsals are best fixed through a longitudinal medial incision (on the upper edge of the abductor hallucis tendon) and a longitudinal lateral incision (on the upper edge of the abductor digiti tendon).

4.2.4 **Fractures of the proximal fifth metatarsal**

Intraarticular fractures of the proximal fifth metatarsal are best treated nonoperatively, even if the fracture is displaced. Treatment is symptomatic, reducing pain while walking with adequate means such as a cam walker [10]. Extraarticular, metaphyseal fractures, so-called Jones fractures, undergo high local strain due to the pull of the fibularis tertius muscle. Surgical treatment by primary open reduction and fixation with a plate and 2.4 or 2.7 mm screws can be considered.

5 **Fractures of sesamoid bones**

These are rare fractures and usually heal spontaneously. In case of persisting pain that can be attributed to such an injury, ORIF with one or two 1.5 mm screws may be indicated (Fig 6.10.2-14).

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**Fig 6.10.2-13a–b** Fixation of unstable second and third metatarsal fractures.

**Fig 6.10.2-14** Painful lateral sesamoid fracture fixed with two 1.5 mm lag screws.
6.10.2 Midfoot and forefoot

6 Bibliography


