Talus Fracture

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1 Introduction

Talar fractures are relatively uncommon, accounting for less than 1% of traumatic injuries to the skeleton and 3–5% of all foot fractures [1]. A high energy mechanism usually involved in a unique anatomical context with no musculotendinous junctions, cartilage coverage on almost 60% of its surface and a single major source vascular supply, make them challenging injuries with potentially devastating clinical consequences and high rate of complications related to their management [2–4].

2 Anatomical and Epidemiological Considerations

The talus is characterized by a particular morphology that includes five regions divided into three main segments and two apophyses, all of which can be affected by different traumatic injuries. Most of them are concentrated in two locations: the neck, the narrowest and weakest region where 50% of the fractures are located; and the body, the largest and predominantly articular segment, where up to 30% of the fractures are produced. The remaining 20% corresponds to peripheral sectors of the structure of the talus that includes the head. This segment constitutes, along with

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the navicular bone and the anterior and middle facets of the calcaneus, an area denominated “acetabulum pedis” responsible for the rotatory movement of the midfoot on the rearfoot; the lateral process, a prolongation of the body that presents a double articular surface for the distal fibula and for the lateral end of the posterior facet of the calcaneus and it is the site of insertion of ligamentary structures involved in the stability of the articulations of the ankle and subtalar [1–3]. The region less frequently compromised corresponds to the posterior process, apophysis divided in two tubers. Between both tubers lies the flexor hallucis tendon: the larger posterolateral and articular corresponding to the roof of the posterior subtalar joint and the smaller posteromedial and extra-articular where the tibiotalar segment of the deltoid ligament is inserted (Fig. 1) [2–4].

With respect to its vascular anatomy, talar irrigation depends on the posterior tibial, peroneal perforator, and dorsal pedis arteries, which form a complex network of extraosseous circulation [5–7]. The most important component of this network is the connection between the artery of the tarsal canal – originating from the posterior tibial artery 1 cm proximal to the emergence of the lateral and medial plantar arteries – and the artery of the sinus tarsi – branch of the peroneal perforator – since almost two-thirds of the body’s intraosseous circulation comes from it. This anastomosis is located in the sulcus tali, a cleft that runs along the lower surface of the

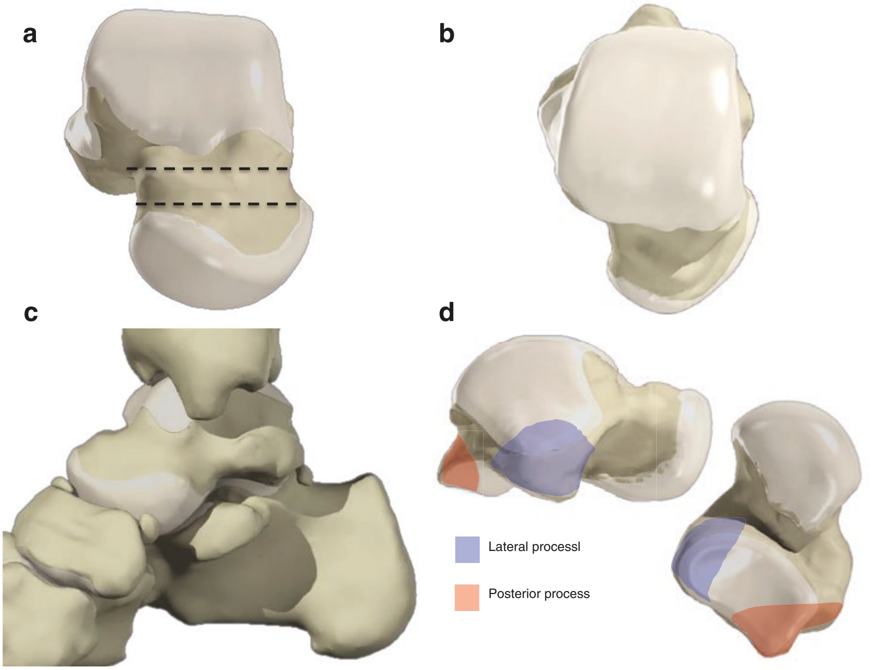

Fig. 1 Schematic representation of the bone anatomy of the talus. (**a**) Anterior view. (**b**) Superior view. (**c**) Medial view. (**d**) Lateral and inferior view

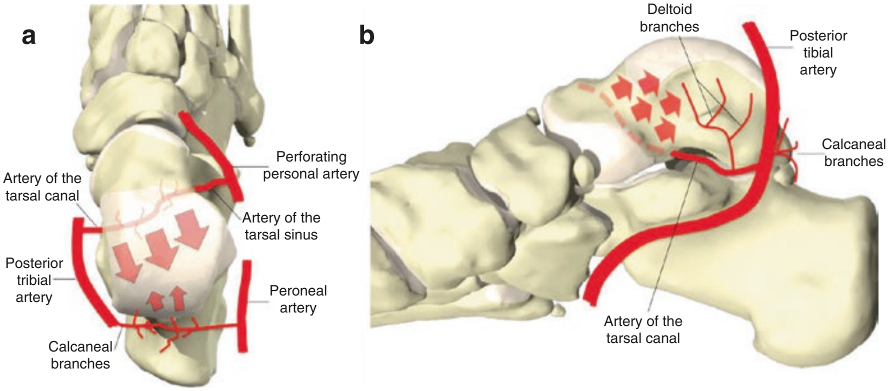

Fig. 2 Schematic representation of extraosseous network around the talus. Big red arrows show main retrograde flow to the body from connection between tarsal canal artery-artery of the tarsal sinus. (**a**) Superior view. (**b**) Medial view

talus from posteromedial to anterolateral, narrower on the inside (tarsal canal) than on the outside (sinus tarsi) and which, through small transcortical tunnels called foramins, allows vascular entry. The second anastomosis in importance is located in the region that surrounds the posterior process and is formed by calcaneal branches dependent on the posterior tibial artery and branches coming from the peroneal artery. Small vessels enter the body and establish communications with those coming from the anastomosis of the sulcus talis determining a “anterograde flow” of smaller quantitative value. Finally, there are minor contributions depending on the deltoid branch, a direct tributary of the posterior tibial artery in charge of supplying the medial third of the body, and from branches of the sinus tarsi artery that supplies the lateral fifth of the astragaline dome (Fig. 2). In summary, most of the body’s intraosseous circulation depends on the posterior tibial artery as its main source, with a minor participation of the peroneal perforating artery. The irrigation of the head, on the other hand, corresponds to branches coming from the dorsalis pedis artery (Fig. 3) [7, 8].

3 Mechanism and Lesional Physiopathogenesis

The fractures of the three main segments of the talus share in their origin a high-energy mechanism, because significant forces are needed to compromise structures constituted fundamentally by highly resistant subchondral bone. Most of them result from falls from heights or traffic accidents and a high percentage are produced in the context of polytraumatized patients or with multiple injuries [1–3, 9]. For this reason, they are usually also associated to different degrees of soft tissue compromise or to other injuries of neighboring joints. Neck fractures are primarily caused by a mechanism of forced ankle dorsiflexion which acts in stages. First, it leads to anterior tibia

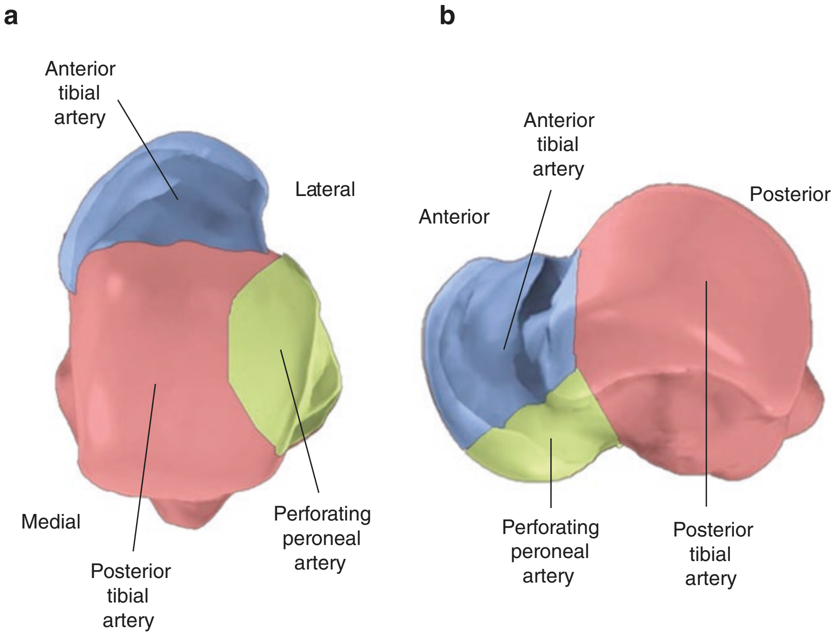

Fig. 3 Schematic representation of internal vascularity of the talus showing the posterior tibial artery and branches as the major blood source to the body of the talus. (**a**) Dorsal view. (**b**) Medial view

impaction. As the dorsiflexion force of the foot continues to act, the energy of the trauma propagates through the neck and toward the subtalar joint, causing the progressive subluxation of the body with respect to the calcaneus progressing to dislocation or complete enucleation from the ankle (Fig. 4a–c). This primary dorsiflexor force usually has associated a secondary component of forced supination of the foot, which produces a failure in tension of the lateral side of the neck and in compression of its internal side, resulting in medial comminution, shortening and varus, and finally the probable appearance of a vertical fracture of the medial malleolus [9–11]. The fractures of the body generally result from a mechanism of axial compression of high energy applied between the calcaneus and the tibial pilon, although also they can be secondary to a mechanism of shearing similar to that of the injuries of the neck that generates a more posterior line [11]. The fractures of the head can be related to two mechanisms of high energy: a compression mechanism by an axial load transmitted through the metatarsal-navicular-talar axis which results in a comminuted injury of the medial portion of the head; or a shearing mechanism by a mediotarsal inversion-adduction force in which the navicular bone impacts the head generating a simple fracture line with two well-defined head fragments (Fig. 5a–c) [11].

Process fractures, on the other hand, are more frequently observed in the context of medium-energy trauma produced during the practice of certain sports activities. Lateral process fractures are characteristic of snowboarding (“snowboarder’s

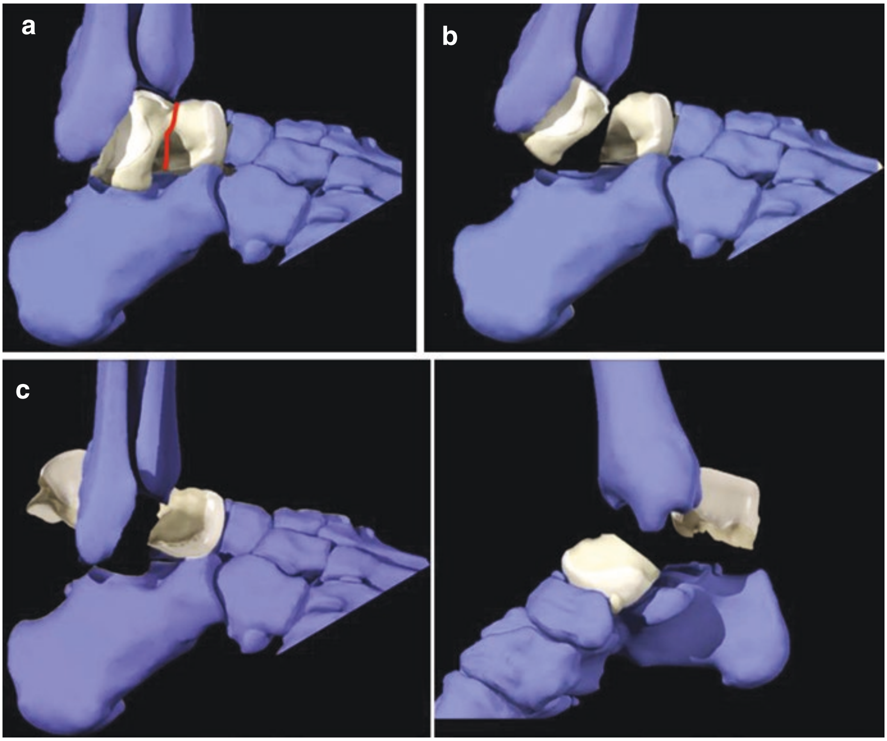

Fig. 4 Schematic representation of the neck fracture mechanism. (**a**) Impact of the tibialis anterior plafond on the neck of the talus. (**b**) Subtalar subluxation. (**c**) Complete dislocation/enucleation of the body in lateral and medial view

fracture") since the causal mechanism is an axial load or forward fall on an ankle in dorsal flexion and forced external rotation or eversion of the hindfoot, a common situation in this winter sport [12]. The fractures of the posterior process have been associated with soccer and ballet dancing since they are generally secondary to a direct mechanism of forced plantar flexion of the foot that causes compression of the posterior tibial plafond against the posterolateral tubercle, or to an indirect mechanism in forced dorsal flexion and inversion of the ankle that results in an avulsion fracture by traction of the posterior talofibular ligament [13, 14]. Both processes can also be compromised in the context of high-energy trauma, particularly when there is a history of subtalar dislocation [14, 15].

4 Clinical and Imaging Diagnosis

Clinical findings associated with high-energy neck or body fractures are evident and include the presence of pain, swelling, and bruising of varying but usually severe magnitude as well as some degree of deformity in the case of concomitant

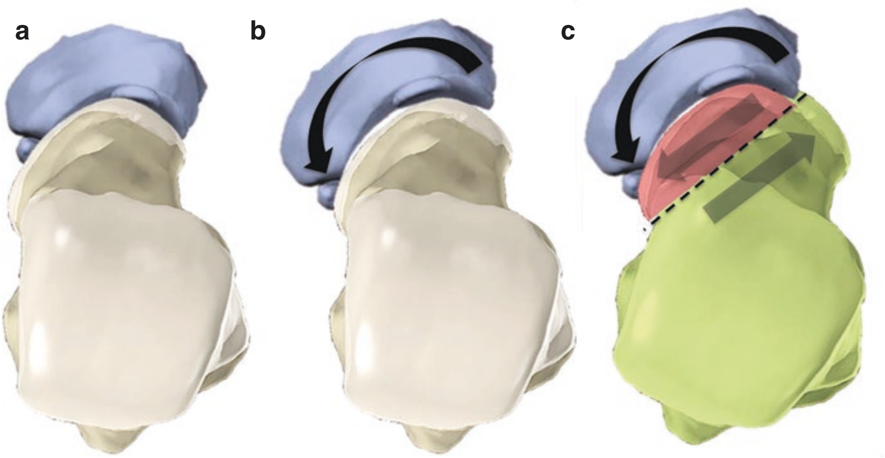

Fig. 5 Schematic representation of the mechanism of fractures of the head of the talus. (**a**) Normal relationship. (**b**) The navicular articulates around the talar head. (**c**) With an axial load, a shear force is created that produces the fracture

peritalar dislocations. Similarly, different degrees of soft tissue injury can be observed in relation to the energy of the trauma, which can include everything from superficial abrasions or abrasions to coverage defects located in general on the lateral face of the ankle or rearfoot. However, it is not uncommon for the diagnosis to be delayed in the context of the polytrauma patient, which is why a thorough physical examination is recommended in an unconscious patient in the intensive care unit [15–17]. Process fractures, on the other hand, tend to present a less spectacular clinical picture similar to that of other traumatic bone or soft tissue injuries in the region, with pain, swelling, and perimalleolar hematoma and a certain degree of restriction of the range of active and passive mobility of the ankle, subtalar, or medial-osseous joints. This fact added to a more difficult radiological visualization of the processes determines that its initial diagnosis can go unnoticed up to 50% of the cases [12, 18].

The radiographic study in cases of clinical suspicion must include the two classic anteroposterior and lateral projections of the ankle and, in the event that the contour of the talus cannot be correctly visualized in the anteroposterior view, a mortise oblique with internal rotation of 15°. Lateral radiography is usually the most useful for interpreting the injury, since it shows a fracture of the body or neck with relative ease, and in the case of fractures of the processes, it allows the suspicion of this lesion (Fig. 6a, b) [12, 15–18]. X-rays of the foot in frontal, lateral, and oblique projections should be requested routinely to correctly evaluate the head segment and to rule out peritalar dislocations or other associated medial or forefoot injuries. The specific Canale and Broden projections have lost relevance in the initial diagnostic phase, although they remain absolutely valid as methods of intraoperative control of the quality of reduction achieved during surgical fixation. The Canale projection allows control of the alignment achieved in the coronal plane especially

Fig. 6 (**a**) Clinical/radiological presentation characteristic of a high-energy fracture of the talar neck. (**b**) Clinical/radiological presentation characteristic of a fracture of the lateral process of the talus. Note how the lateral process loses its symmetrical V-shape contour and is projected in a twisted or asymmetrical V-shape

in neck fractures: it is taken with the foot in maximum plantar flexion and 15 degrees of pronation and the X-ray beam directed in a cephalic direction and pointing 75° with respect to the horizontal (Fig. 7a). The Broden projection allows evaluation of the congruence of the subtalar joint: it is taken with the foot in a neutral position and internal rotation of 20–60° with respect to the vertical and the X-ray beam directed in a cephalic direction of 10–40° with respect to the vertical (Fig. 7b) [1, 2, 11, 16].

Computed axial tomography is the study of choice for correct interpretation and decision making in fractures of the talar neck and body. It allows evaluating the exact location of the fracture, the degree of displacement, its morphological pattern characterizing it as simple or comminuted, the involvement of the neighboring joints, and the presence of associated injuries, key aspects to define the type of treatment and plan the surgery if necessary. In the case of acute fracture-dislocations, it is convenient to perform it after the reduction of the main fragments. In the same way, the tomographic study with multiplanar cuts every 1–2 mm is especially useful to identify and characterize the fractures of the processes, defining the size of the fragments, the degree of displacement, the presence of comminution, and the percentage of the subtalar or tibiotalar joint compromise [1–3, 15, 17, 18].

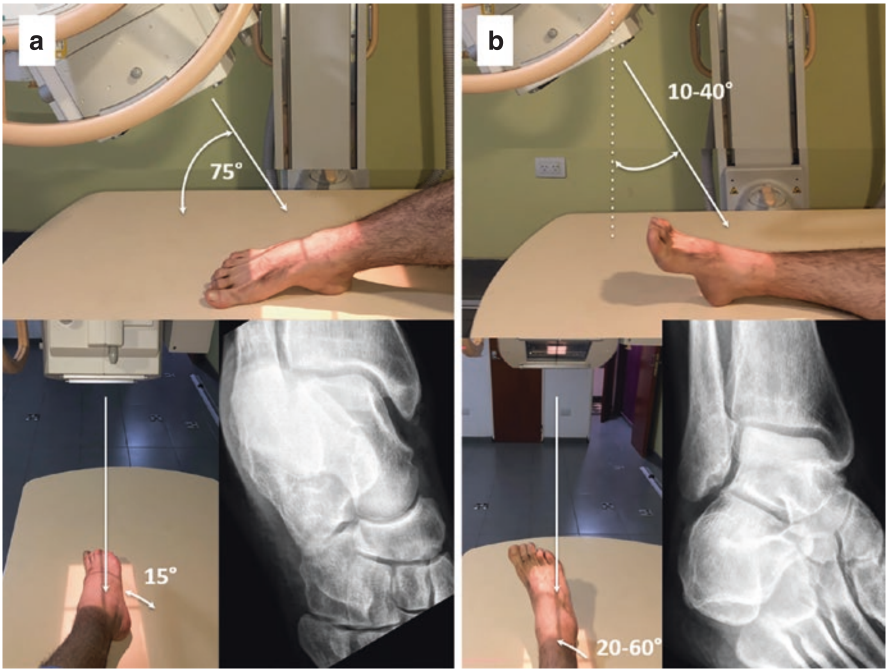

Fig. 7 Specific projections for the talus and subtalar joint. (**a**) Canale projection. (**b**) Broden projection

5 Management Criteria

5.1 Neck Fractures

Hawkins' (1970) [19] radiographic classification, which divides these injuries into four types according to the involvement of the surrounding joints, is a descriptive system of prognostic value based on the body's vascular involvement which, with modifications and evolutions, has lasted over time as a useful tool for decision making. Type I fractures are non-displaced fractures of the neck that do not affect any joint surface and that in theory only interrupt anterolateral blood flow, for which they are associated with a low risk of avascular necrosis of the body (AVN) that ranges from 0% to 13%. They can be treated conservatively, with a protocol that includes immobilization and unloading of body weight with two crutches for 8–10 weeks, biweekly radiographic control, and total weight load at full consolidation, usually at 12 weeks. Alternatively, stable internal fixation with screws through a minimal posterolateral incision may allow earlier functional rehabilitation by reducing the risk of secondary displacement, vicious consolidation, or pseudoarthrosis (Fig. 8) [16, 19]. Type II fractures involve displacement of the subtalar joint, with the possibility of interruption of the circulation entering the neck both at the

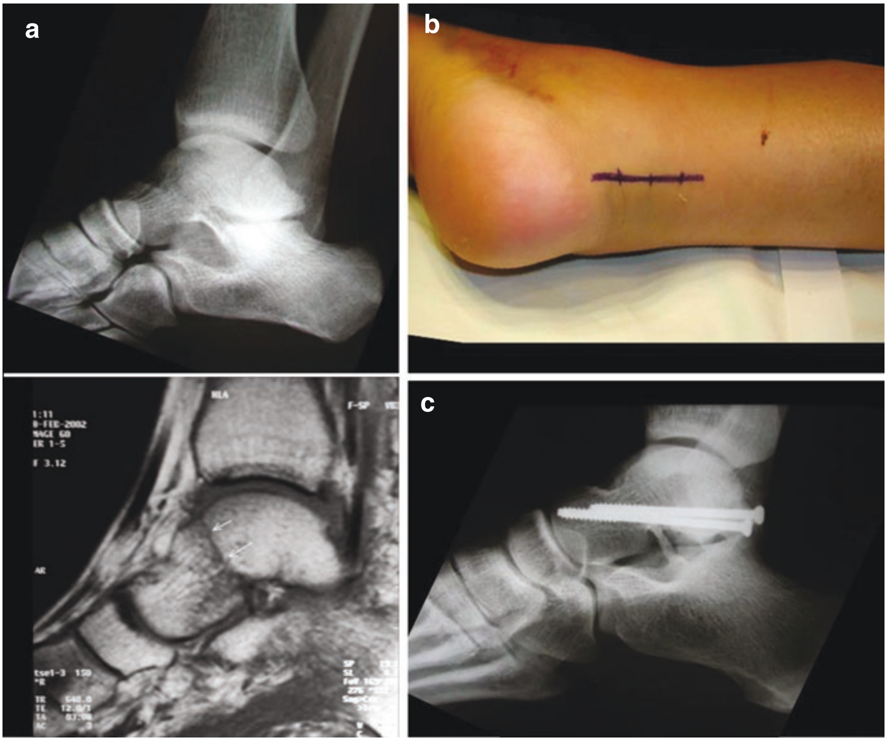

Fig. 8 A 17-year-old female patient. Hawkins type I fracture. (**a**) Perioperative studies. (**b**) Posterolateral route for percutaneous fixation. (**c**) Postoperative Rx

anterolateral level and through the sinus of the tarsus and a risk of AVN of the body ranging from 20% to 50% according to Hawkins' classic description. Recently, Vallier et al. have divided them according to the degree of joint displacement into two subtypes: IIa, where the joint is subluxated, the rate of VAP is similar to that of type I, and the rates of subtalar and tibiotalar arthritis are lower (21% and 5.3% respectively) (Fig. 9a); and type IIb, where the joint is dislocated, the rate of VNA is high (25%), and the rates of subtalar and tibiotalar arthritis are higher (25% and 13% respectively) (Fig. 9b) [20]. Although they do not constitute a surgical emergency since the delay in definitive fixation does not predispose to the development of osteonecrosis [21, 22], the lesions associated with subtalar dislocation (IIb) require active behavior in the emergency through closed manipulation and transitory stabilization to protect soft tissues and preserve body's vascularization. The recommended technique for joint reduction includes the distraction of the ankle and hindfoot from the calcaneus through a transfixed calcaneus wire of 2.5 mm followed by a posterior translation looking for subtalar facet reduction. If necessary, a trans-articular temporary stabilization can be applied (Fig. 10). Type III fractures – which involve the dislocation of the talar body off the subtalar and tibiotalar joints with posteromedial extrusion of the same given that it rotates around the deep deltoid

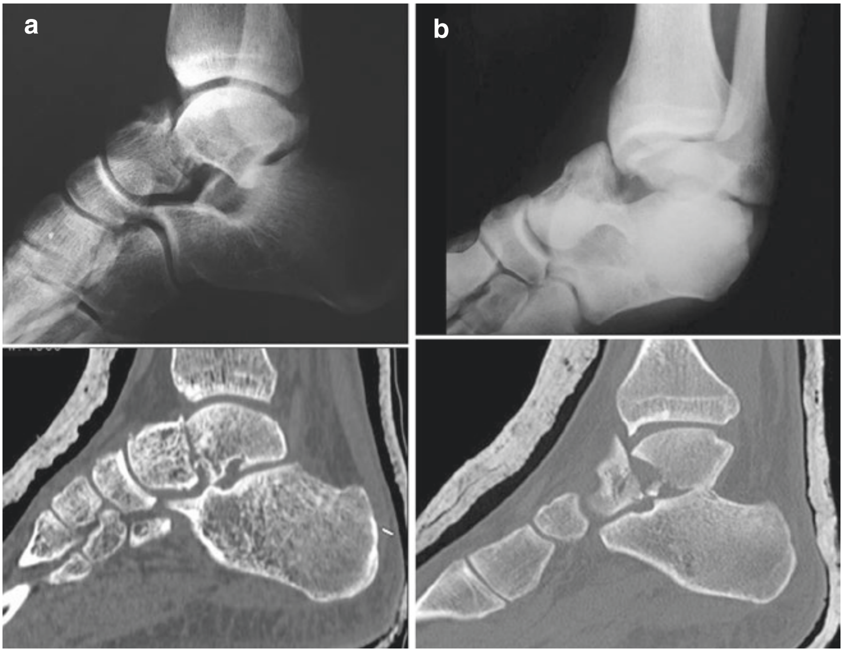

Fig. 9 (**a**) A 27-year-old male patient. Hawkins' type IIa fracture. (**b**) A 24-year-old male patient. Hawkins' type IIb fracture

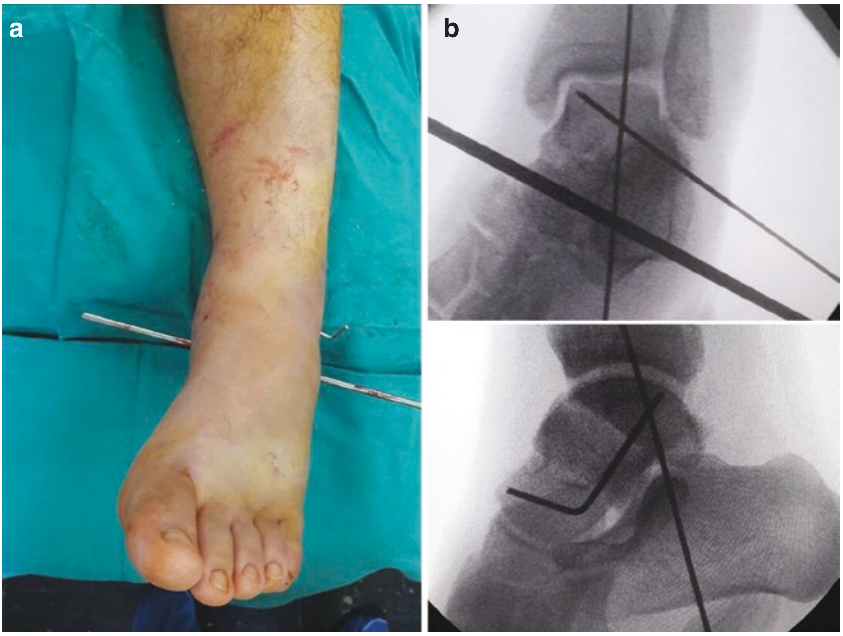

Fig. 10 Same patient as Fig. 9b. (**a**) Calcaneal K-wire for closed reduction. (**b**) Intraoperative radioscopic vision after reduction and osteodesis

Fig. 11 A 32-year-old female patient with Hawkins III astragalus neck fracture. Note the position of the talus body outside the ankle mortise on the Rx (arrows)

ligament (Fig. 11) – and type IV fractures – category of injury added by Canale and Kelly which involves the subluxation or dislocation of the talonavicular joint (Fig. 12). Type III and IV can compromise all three sources of the talar body's blood supply, thus being associated with extensive circulatory involvement of the body with a risk of VAS of 70–100% and possible vascular suffering of the head. They both constitute a traumatic emergency and, like IIb lesions, must be reduced and temporarily stabilized on admission, although unlike the latter, closed manipulation is generally not effective and requires percutaneous procedures or formal open (usually medial) approaches for reduction. The use of a large fracture distractor can be of great help, providing space for the reduction in a progressive way under radioscopic control avoiding forced manipulations of the body. In the case of open lesions, the initial handling includes the immediate administration of antibiotics by parenteral route and the irrigation and urgent debridement of the wound. The final treatment follows the same principles of anatomical reduction and stable internal fixation as for type II fractures.

The surgical technique at the time of definitive osteosynthesis in neck fractures may include a single approach or a combined double access. The most frequently cited single approach is the anteromedial approach, which begins on the anterior margin of the medial malleolus and progresses into the tuberosity of the scaphoid, running halfway between the anterior tibial and posterior tibial tendons and behind

Fig. 12 A 48-year-old male patient with Hawkins IV astragalus neck fracture. Note the talonavicular incongruence in the axial section of the CT

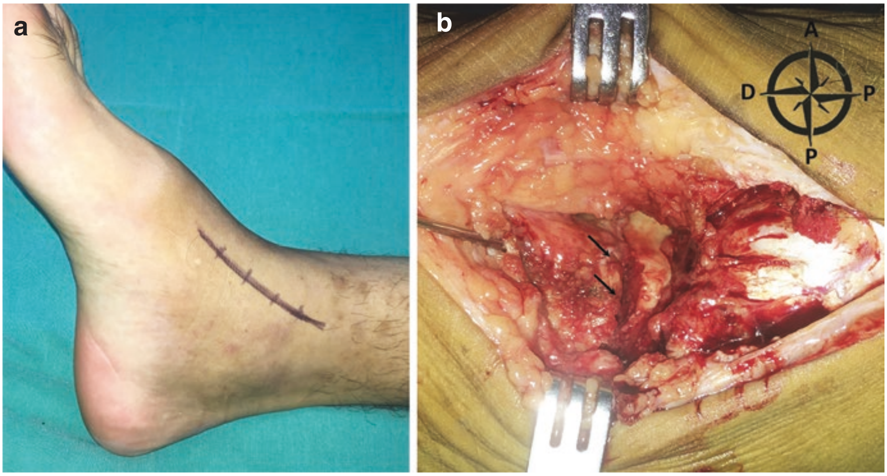

Fig. 13 Anteromedial approach. (**a**) Conventional incision from the medial malleolus to the navicular. (**b**) Intraoperative view of the fracture line (black arrows)

the nerve and saphenous vein, giving access to the more inferomedial side of the neck (Fig. 13) [9, 21, 23–25]. Another alternative is the anterior approach that begins about 3 cm proximal to the ankle joint outside the tibial crest and extends distally following the lateral margin of the anterior tibial tendon (ATT) in the interval between the ATT and the extensor hallucis longus (EHL), allowing adequate exposure of the dorsal surface of the neck, but very limited exposure of its two lateral faces (Fig. 14) [24, 25]. The main disadvantage associated with the single-approach technique is inadequate visualization: only the medial or superior cortex can be directly accessed and verified, which may appear perfectly aligned but coexist with an opening or loss of contact of the main fragments on the contralateral side (Fig. 15). This situation can lead to inadequate compression of the fracture with

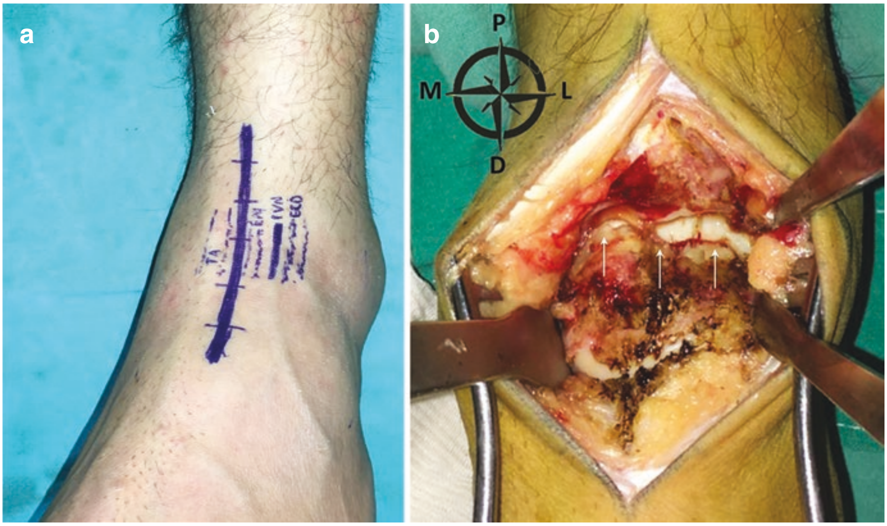

Fig. 14 Anterior approach. (**a**) Incision between the tibialis anterior and extensor hallucis tendon. (**b**) Intraoperative view of the dorsal neck region and fracture line (white arrows)

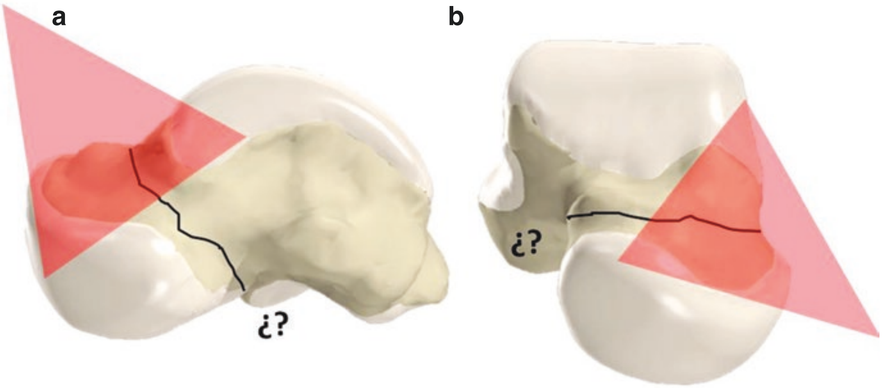

Fig. 15 Area of direct visual control by a single approach. The (**a**) dorsal or (**b**) medial region of the neck can be accessed but not the full extension of the fracture site

shortening of the neck or to an inclination of the fragment which inevitably has functional repercussions: a poor dorsal or varus reduction of no more than 2 mm alters the congruence and the subtalar movement and is associated with degenerative phenomena in up to 30% of cases [19]. Similarly, the single-approach strategy admits very limited reduction maneuvers and allows only screws to be placed for fixation, which is why it is no longer used and is only suggested in the scenario of simple fractures without comminution and with minimal initial displacement (Fig. 16) [21, 23–25]. Combined lateral and medial access is the current modality most recommended, especially in complex patterns (Fig. 17), since it is possible to better visualize both sides of the segment and thus better control reduction by avoiding residual displacement invariably associated with poor functional outcome. Of the most frequently cited lateral approaches in the literature, Bohler's classic sagittal approach is apparently the most anatomical [21, 24, 26–29]: the incision is made slightly curved from the anterolateral apex of the ankle joint in line with the extensor digitorum longus and peroneus tertius tendons towards the sinus tarsi and the base of the fourth metatarsal. Deep dissection continues up to the articular capsules of the ankle and subtalar joints. The short toes extensor muscle (extensor digitorum brevis) in a distal direction can be reflected plantarly, thus exposing the most distal portion of the lateral neck (Fig. 18). For some authors, the lateral Ollier approach is

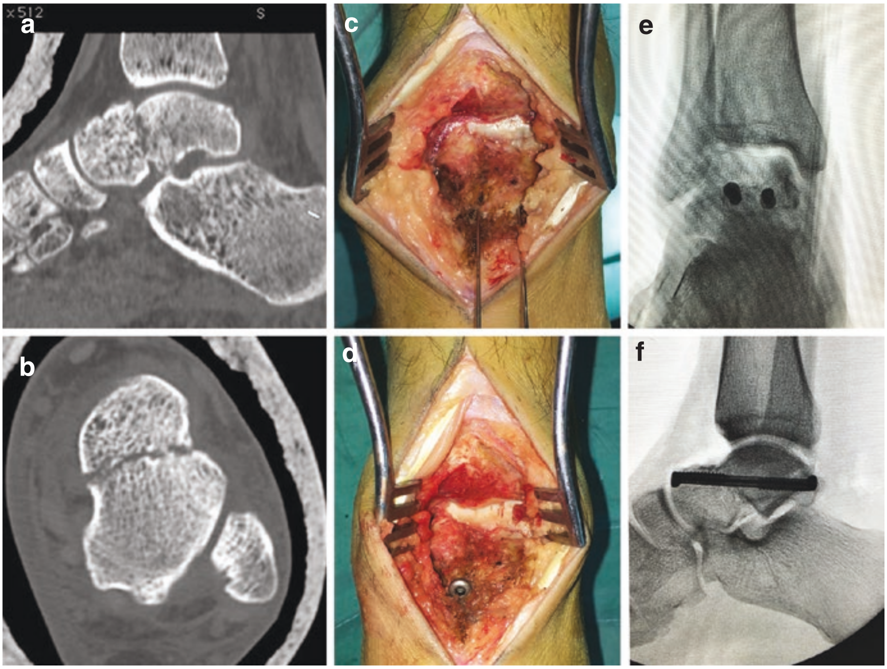

Fig. 16 A 24-year-old male patient. (**a**, **b**) Preoperative CT showing simple vertical neck fracture without comminution and with minimal initial displacement. (**c**, **d**) Intraoperative view of reduction and fixation by single anterior approach. (**e**, **f**) Anatomic reduction confirmed by radioscopy

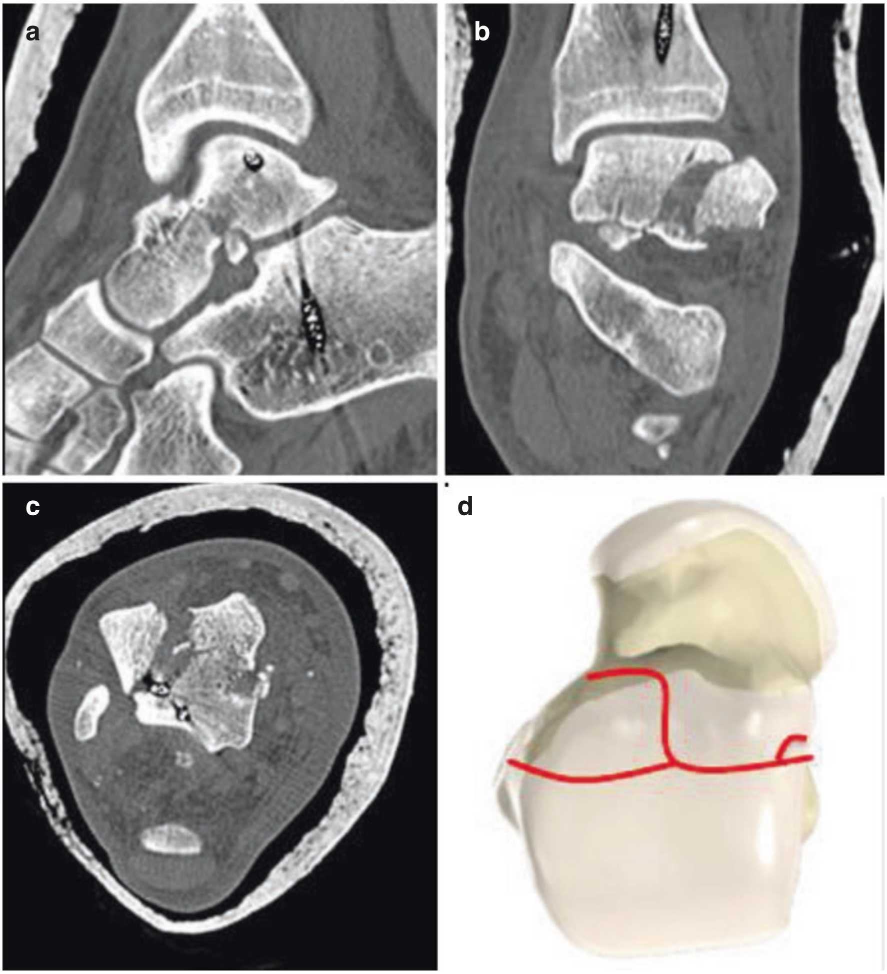

Fig. 17 Same patient as Figs. 9b and 10. (**a**–**c**) CT shows a complex pattern with extension to the body. (**d**) Schematic representation of the fracture pattern

more effective [24, 30]: this incision extends from the tip of the lateral malleolus to the neck of the talus, sectioning the inferior extensor retinaculum and identifying the peroneus tertius and the short hallux extensor itself, which retract medially in the superior part (distal) of the wound leaving the peroneal tendons in the inferior part (proximal). After partial removal of the fat pad on the sinus tarsi, the entire lateral talar neck can be accessed. In this dual strategy, the lateral approach is generally performed first, since the lateral neck is the tension side and usually has no comminution allowing the displacement and rotational misalignment correction more easily achieved. Similarly, in most cases there is a cortical bone spike on the lateral neck that provides a reference to help achieve an accurate anatomical reduction by means of a pointed clamp (Fig. 19) [24]. The temporary wire through the posterior

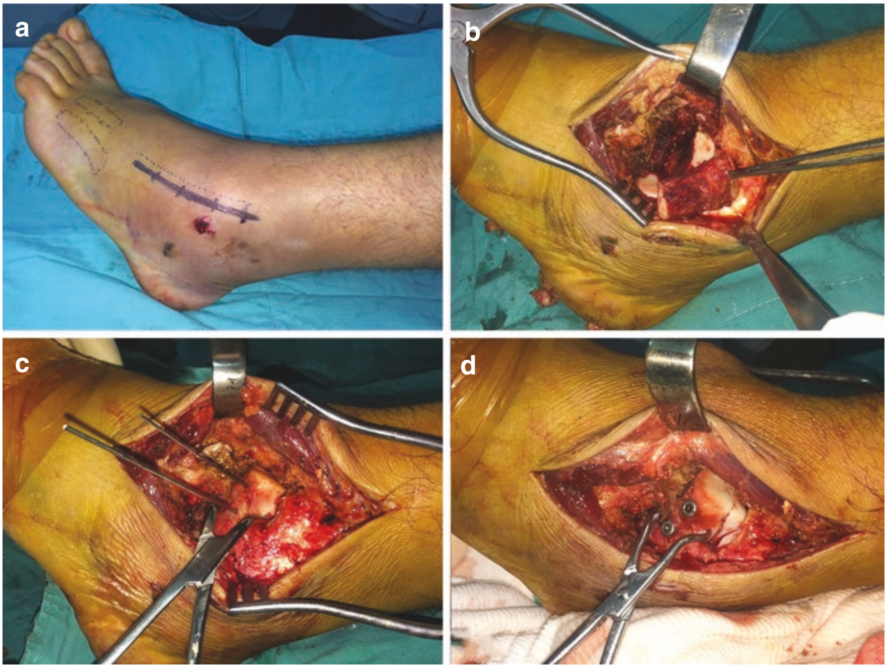

Fig. 18 Intraoperative view of the anterolateral approach of the patient from Figs. 9b, 10, and 17 (**a**) Skin incision. The displaced body fragment (**b**) was reduced and fixed with K-wires (**c**) and two 3.5 mm screws. Subsequently, the neck fracture is reduced with a Weber clamp (**d**)

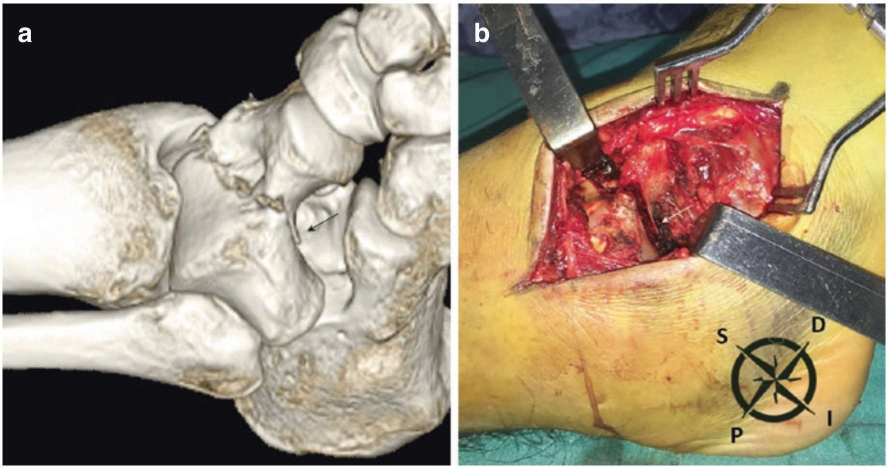

Fig. 19 Cortical bone spur (arrows) usually present on the lateral neck. (**a**) 3D CT image. (**b**) Intraoperative view

subtalar facet can be very useful in this instance by providing a fixed point on which to adjust the distal fragment. Similarly, strong K-wires (2.5 mm.) can be used as a "joy-stick" to correct some residual fragment pronation or supination [24]. Once the lateral reduction has concluded, the anteromedial approach described above is initiated from the anterior margin of the medial malleolus to the talonavicular joint and the dorsal margin of the posterior tibial tendon sheath distally. The reduction achieved must be visually verified so that if it is anatomical, definitive fixation can proceed (Fig. 20). If there is severe medial comminution, the use of autografting is suggested to maintain the medial length and prevent varus reduction. With respect to the fixation technique for the simplest patterns, two 3.5 mm full-threaded screws can be used, one on each side of the neck, placed from the margins of the head and directed towards the body. It is recommended to insert the first screw laterally because normally there is no comminution on that side of the neck and it is better to grasp the denser cortical bone in that area and conveniently countersink the entry site so that it is below the plane of the articular cartilage and subchondral bone. Compression should be avoided especially in the presence of medial comminution to avoid a varus or shortening neck malunion [24, 29, 31–33]. The antegrade

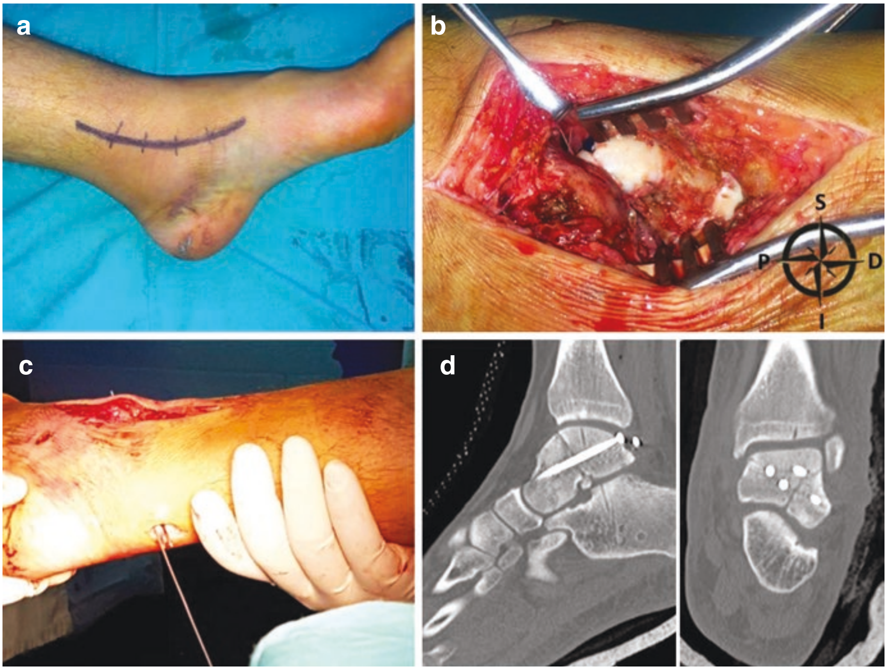

Fig. 20 Same patient as Figs. 9b, 10, 17, and 18. (**a**) Skin incision. (**b**) Anatomical reduction control from the medial side. (**c**, **d**) Definitive fixation with two 3.5 mm posterior-anterior screws

placement of the screws by a small posterolateral approach lateral to the flexor hallucis longus tendon from the lateral posterior process towards the head is biomechanically superior and provides a more rigid construct [34], but it is associated with some difficulties that make its indication much more exceptional: instrumentation more difficult since the patient is positioned in supine position, neuropraxia of the sural nerve, posterior ankle impingement due to screw head conflict with the posterior malleolus, and possibility of injury to the branches of the sinus tarsus anastomosis (which may increase the risk of necrosis of the body) [32, 33]. In more complex patterns associated with greater initial displacement and greater comminution, the use of 2.7 mm diameter mini-fragment plates allows for a more rigid fixation than that achieved with screws alone. Although they can be placed both on the compression face (medial) of the neck with a support function and on the tension face (lateral) to maintain the length and alignment of the segment, the most frequently used construct consists of a plate with four screw holes contoured to the lateral neck fixed with unicortical screws (Fig. 21). The medial talar usually allows little space for the placement of plates due to the wide footprint of the joint with the medial malleolus [27–32].

The postoperative protocol includes immobilization of the ankle and foot in a brace for 2 weeks, active and passive mobility exercises starting on day 15, and

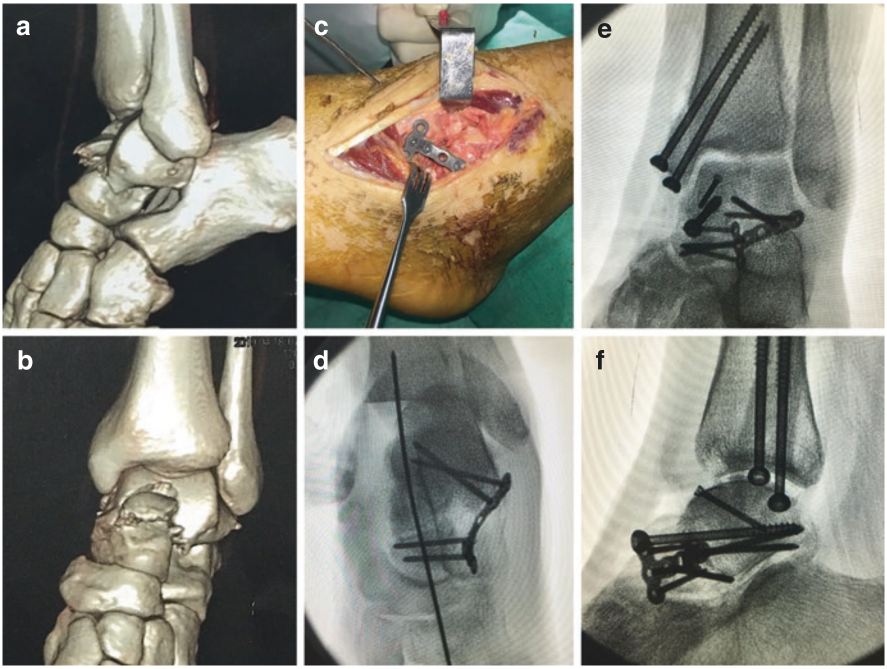

Fig. 21 A 24-year-old female patient with complex talar fracture Hawkins II. (**a**) and (**b**) preoperative 3D CT. (**c**) Intraoperative view and (**d**) radioscopic image at the end of lateral time. (**e**) and (**f**) Radioscopy image at the end of surgery

unloading of the body weight for 10–12 weeks. Radiological controls are monthly until healing, looking for around 6–8 weeks the appearance of “Hawkins’ sign”, subchondral lucidity of the body that is a positive predictor of revascularization, and therefore implies a low risk of avascular necrosis.

5.2 Body Fractures

From the descriptive/physiopathogenic point of view, three main patterns of body fractures can be recognized, included within historical classifications, such as Sneppen (1977) [35] or more modern ones such as AO/OTA (2018) [36] (1): Vertical shear fractures including two fragments in the coronal or sagittal plane involving only the ankle joint or the ankle and subtalar joint (2); multi-fragment compression fractures involving only the ankle joint; and (3) multi-fragment compression fractures involving the ankle and subtalar joints, also called crush fractures (Fig. 22). The treatment of choice in any of these scenarios is open reduction and internal

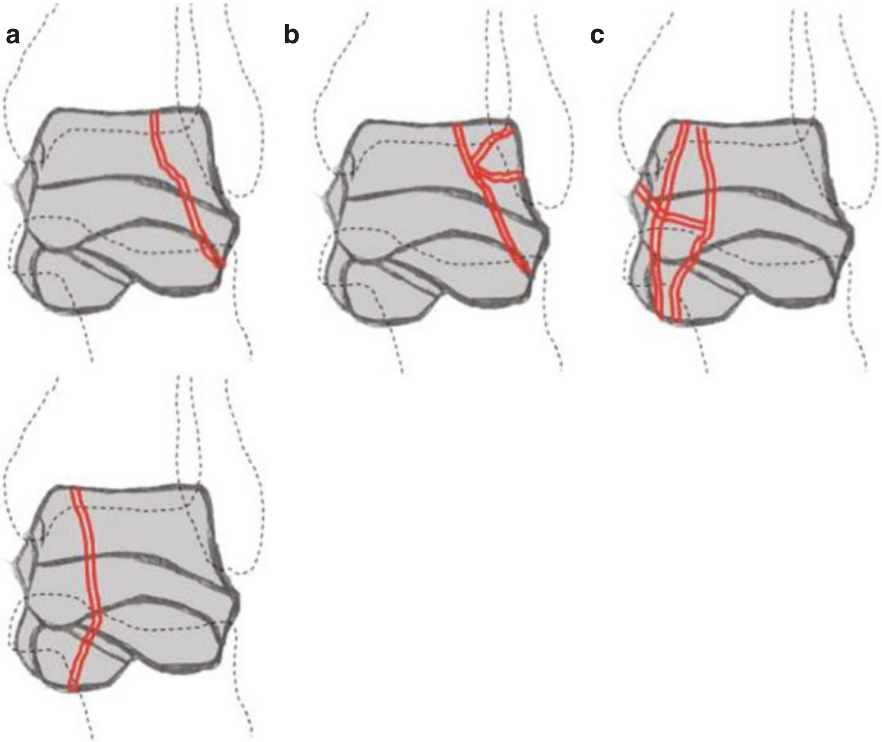

Fig. 22 Main patterns of body fractures (**a**) Simple patterns. (**b**) Multifragmentary patterns involving only the ankle. (**c**) Multifragmentary patterns with tibiotalar and subtalar involvement (crushing)

fixation with the aim of accurately restoring joint congruence and segment alignment. The initial management in the emergency implies the close or open reduction of the associated dislocations, temporary stabilization if necessary, and the irrigation and debridement in open lesions with the objective to preserve the soft tissues and to avoid infection. Definitive treatment can be deferred for 1–3 weeks since, as in neck lesions, there is no association between fixation time and the development of osteonecrosis [9, 37].

The selection of the surgical approach is based on the location and the fracture pattern, but generally implies the need to extend the visualization directly to the back of the body by clearing the malleoli by means of an osteotomy. The most commonly described is the medial malleolar osteotomy: first the medial malleolus screws are positioned on the medial malleolus and then removed. Then, the osteotomy is made in 45° from the tibia axis, with its exit point at the tibial plafond medial shoulder, reflecting the malleolus distally and preserving the deltoid ligament (Fig. 23). In a similar way, a suprasindesmal transverse osteotomy of the fibula can be performed to gain access to the posterior-lateral part of talar body, after section of the anterior-inferior tibiofibular ligament and externally rotating the bone segment, i.e., "open book". Rigid fixation in shear fractures in the coronal plane is achieved in the same way as in neck fractures through two 3.5 mm screws placed from the medial and lateral edges of the talar head directed longitudinally towards the body (Fig. 24). In case of associated involvement of the lateral process, a medial screw and a lateral mini-fragmentation plate can be combined. For shear fractures in the sagittal plane, fixation with countersunk traction screws at the entry site is preferable to avoid protrusion of the implant. In case of partial or complete

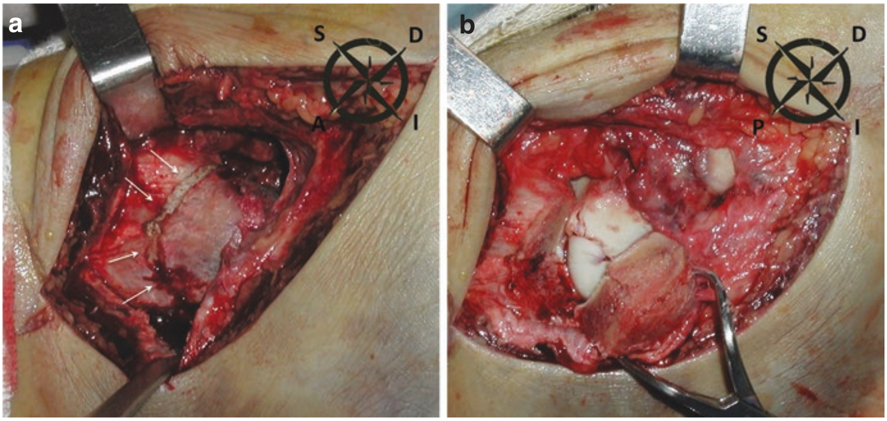

Fig. 23 Extended anteromedial approach by osteotomy of the medial malleolus (**a**) Chevron type-osteotomy with the apex proximal to the tibial plafond (arrows). (**b**) Distal fragment mobilized downwards giving access to the body

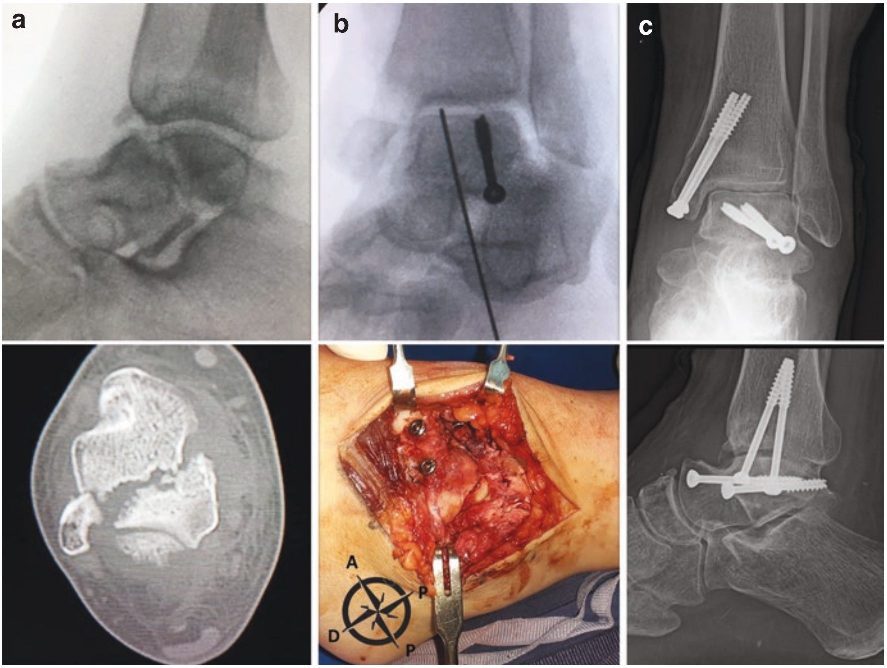

Fig. 24 A 26-year-old female patient with talar body coronal fracture. (**a**) Preoperative studies. (**b**) Intraoperative imaging. (**c**) Rx at 5 months postoperative

articular multi-fragment compression fractures, fixation of the main fragments is obtained by mini-fragment implants (1.8 mm, 2.0 mm, 2.4 mm, 2.7 mm), while devitalized fragments that do not contribute to joint stability or joint congruence can be eliminated. The postoperative protocol is similar to that for neck fractures with early mobility and deferred loading no earlier than 12 weeks postoperatively [1, 2, 27–32, 38].

5.3 Fractures of the Head

The treatment of fractures of the talar head depends on the degree of compromise of the talonavicular joint: a displaced injury generates joint incongruence and secondarily limitation of subtalar mobility, shortening of the internal foot column, and deformity in varus, so it must be surgically corrected by open reduction and internal fixation. The preferred access route is anteromedial and fixation is performed by 3.5 mm cortical screws in compression through the fracture focus (Fig. 25). In the cases associated with comminution and substantial shortening of

Fig. 25 A 29-year-old male patient. Single line fracture of the head. (**a**) Preoperative CT scan. (**b**) Postoperative Rx

the medial column, small block grafts are used to recover the original length. A mini external fixator anchored proximally in the body of the talus or in the calcaneus and distally in the scaphoid or the medial cuneiform can be associated to help avoiding talar shortening, which will be maintained until the radiological healing [39].

5.4 Fractures of the Processes

The treatment of process fractures is based on their anatomical morphology, which is considered in all the classifications that try to protocolize their management and that recognize for practical purposes three main types (1): an avulsive variant with a small fragment (2); an intermediate or large single trace fragment variant; and (3) an intermediate or large fragment variant with fragmentation, which can be only articular, only metaphyseal, or affect the entire process (Fig. 26) [40–42]. Conservative management is reserved only for small avulsions without articular commitment, with immobilization for 6 weeks with partial body weight loading (10 kg). In the rest of the situations and due to the fact that displacement is usually the rule, the treatment is surgical.

Fig. 26 Main types of fractures of the lateral process of the talus: (**a**) avulsive, (**b**) simple, and (**c**) with fragmentation

For the anterolateral process, arthroscopic access through two ventral and dorsal anterolateral portals can be an option both for resection-debridement of small intra-articular lesions and for fixation of intermediate to large fragments with minimal initial displacement [40]. Open surgery is the preferred technique for larger lesions displaced through a transverse Ollier access or a slightly curved anterolateral longitudinal access. The use of a universal distractor or a unilateral external fixator with pins placed in the fibula and in the posterior tuberosity of the calcaneus allows the creation of a certain space in the subtalar joint that facilitates the visualization of the fracture. The single patterns can be fixed only with screws since there is a uniform surface of bone contact between the main fragment and the fracture bed (Fig. 27). The minimum size of a potentially “fixable” fragment corresponds to three times the diameter of the screw head to be placed, which can be 2.0, 2.4, or 2.7 mm (“rule of thirds”). Fragmentation patterns need augmentation with a plate, usually at ¨T¨ of 2.0 mm as a support, with the transverse plate branch parallel to the subtalar joint with 3–4 screws in a subchondral “palisade” shape and the vertical branch at the base of the neck immediately in front of the articular facet for the fibula [41, 42]. In case of complete fragmentation of the process, subtotal or total resection can even be considered, taking into account that according to cadaveric studies, resecting a volume of between 5 and 10 cm^3 of the segment is not associated with significant subtalar instability [43].

Regarding the posterior process fractures (posteromedial are called Cedell fractures, posterolateral are called Shepherds fracture), although there are several access options, the most widespread is the open way through a posterolateral approach of 5 cm between the peroneal tendons and the Achilles tendon in the superficial layer and lateral to the flexor hallucis longus tendon in the deep layer. The fixation of the fragment is done only with microfragment screws (1.5, 2.0 or

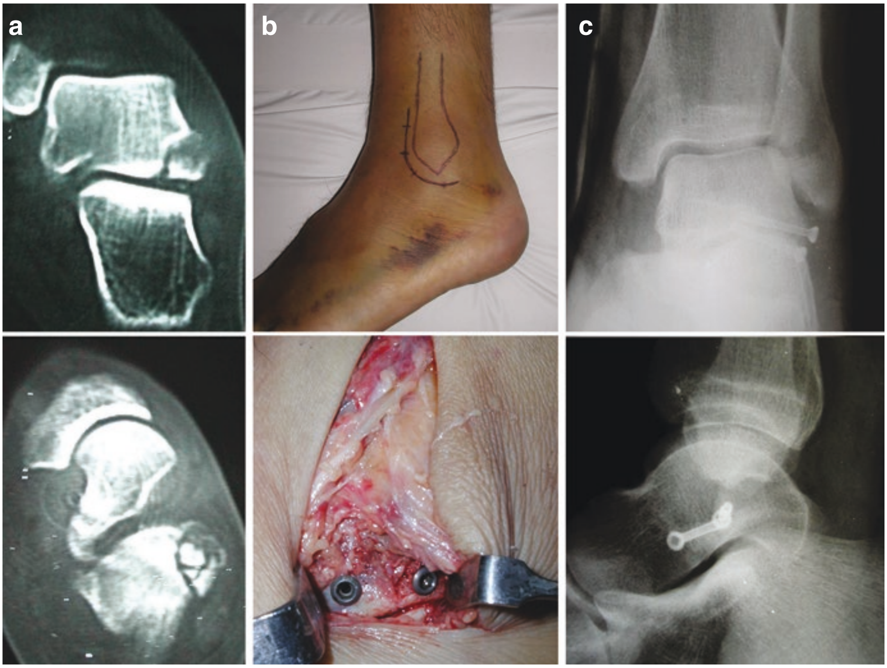

Fig. 27 A 31 year old male patient with lateral process fracture with minimun metaphyseal fragmentation. (**a**) CT scan (**b**) Open reduction and fixation of main fragments by anterolateral approach. (**c**) Final x-ray follow up

2.4 mm) since there is generally not enough space for plate placement (Fig. 28). In case of resection, an arthroscopic approach can be used through two posterior portals with the patient in prone position. The postoperative protocol in process fractures includes early mobility with focus on the subtalar joint and deferred loading from week 8 to 12 [40–42].

6 Results and Complications

The long-term functional outcomes of patients with neck fractures are variable and there is no standardized modality for evaluating them, but in general and as expected, the lower-grade injuries in Hawkins' classification show better results than the higher-grade ones. The most frequently reported complication is subtalar arthritis, whose incidence varies widely from 4% to 100% of cases with a mean of 49% and is secondary to both chondral damage from the initial trauma and nonanatomical reductions, and is clinically well tolerated only in aligned fractures. In symptomatic patients, subtalar arthrodesis as a rescue surgery is effective both for

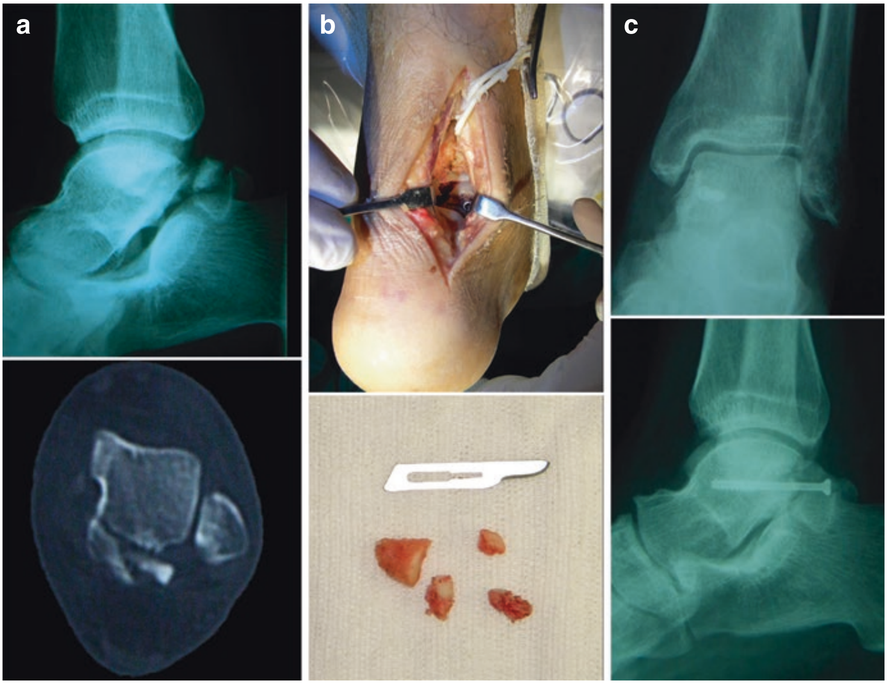

Fig. 28 A 42 year old male patient with posterior process fracture with metaphiseal fragmentation. (**a**) X-ray and CT scan (**b**) Open reduction and fixation of main fragments by posterolateral approach. (**c**) Final x-ray follow up

pain relief and for foot shape. The talar body avascular necrosis (AVN) is another common, although less frequent, sequel that can be conditioned by both the interruption of blood flow due to the trauma and by subsequent surgery. Its overall incidence is approximately 25–30% for all types of fractures, although series published after the year 2000 show lower rates of AVN in Hawkins type II and III injuries probably related to an optimization of their initial and definitive management. Focal AVN without collapse often occurs without significant functional sequelae since in these cases the cartilage survives and the subchondral bone is replaced over time by a "creeping substitution" mechanism. In cases with talar collapse, tibio-talo-calcaneal arthrodesis is usually the main option. Symptomatic nonanatomic healing is another reported complication, with an incidence of between 20% and 37%. The most common malreduction includes leaving the talus shortened and in varus (medial column shortening and varus), which significantly changes the biomechanics of the peritalar joints. Another possibility is that the body heals in excessive plantar flexion, which results in a dorsal prominent talar neck conditioning a friction with the tibialis anterior tendon. Once a malunion is detected, revision surgery of primary osteosynthesis in the acute or subacute scenario or a corrective osteotomy in patients with healed injuries can correct the problem. If left untreated, malunion leads to peritalar arthritis, which requires a rescue arthrodesis to relieve pain and correct the associated deformity. Finally, insufficient fixation of a neck fracture can lead to pseudoarthrosis, a rare complication that can reach up to 4–5% of cases. Rescue includes revision of fixation in the absence of arthritis or a rescue arthrodesis in the case of associated arthritis or insufficient remaining bone stock [44, 45].

Body fractures are potentially devastating injuries commonly associated with complications. The most common is post-traumatic arthritis reported in up to 50–100% of patients, despite the use of modern reduction and fixation techniques. The incidence of AVN, associated with the severity of the original injury and the initial displacement of the fracture, is approximately 40%, and half are associated with collapse. Classic series on immediate surgical treatment of body fractures also report high rates of soft tissue complications of up to 77%, including wound dehiscence, skin necrosis, and infection [9, 10, 28, 46].

The literature on the outcomes of head fractures is sparse. Complications are usually associated with hidden or initially unnoticed injuries, especially in the context of patients with multiple injuries. Although the risk of osteonecrosis is generally low and has been described as less than 10%, secondary arthritis is difficult to manage and is usually treated with arthrodesis of the talonavicular joint [32, 39].

Early diagnosis and treatment are associated with the best results in process fractures as they allow rapid normalization of subtalar function. In large single patterns treated in a timely manner through open reduction and internal fixation, 80% of patients return to their pre-trauma level of function. The most frequently reported complication is arthritis with subtalar rigidity, which can be associated to any fracture subtype even the simplest and with properly performed treatment. The most frequently cited rescue procedures for the treatment of sequelae include subtalar arthrodesis for symptomatic arthritis and partial or subtotal excision of the process for friction syndromes [32, 40].

7 Total Extrusion of the Talus

The most extreme variant of talus dislocation is a total extrusion, uncommon injury with controversial handling with guidelines based on only small case series. Decision-making must weigh the benefits of maintaining the anatomical integrity of the tibiotalar and subtalar joints by reimplanting the segment against the acute and long-term risks of infection, body AVN, and post-traumatic arthritis potentially associated with this procedure. Most authors recommend native talus reimplantation as long as conditions such as absence of gross contamination or severe joint damage are favorable, reserving arthrodesis and talectomy for the treatment of post-reimplantation complications [47, 48].

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