Management of Acute Hindfoot Fractures in Diabetics

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Introduction

Acute fractures of the hindfoot (talus and calcaneus) are among the most challenging injuries to the orthopedic and trauma surgeon. The ultimate goal for these fractures is to obtain an anatomic reconstruction of any joint incongruity and attain an axial realignment in order to obtain a stable, plantigrade foot with near normal joint function [1–3]. Due to the tenuous soft-tissue coverage surrounding the talus and calcaneus, the direct damage to the soft tissues resulting from the injury, indirect damage that occurs through the pressure of displaced bony fragments, and through the use of extensile approaches that are routinely employed for reductions and fixations, one can see why the management of these fractures is prone to minor and major complications [2, 4]. Any malunion, non-union, or postoperative complication leading to a bone infection or resulting in a compromise of the soft-tissue envelope, can lead to severe restrictions of hindfoot function due to joint incongruities, axial mal-alignment, alteration of hindfoot shape, and soft-tissue impingement [5, 6]. Therefore, a balanced approach is needed for patients with relevant comorbidities.

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Acute talar and calcaneal fractures have to be differentiated from pathological fractures, especially those due to diabetes mellitus that often present with an associated polyneuropathy. As a general rule, the suspicion of a neuropathic fracture should be considered in patients presenting with atypical fracture patterns, a history of low-energy trauma, the presence of edema and mild or diffuse pain, and for any patient who presents more than 24–48 h after their initial injury [7]. The associated neuropathy frequently produces an altered pain perception leading to a delay in the diagnosis and treatment, resulting in a progressive destruction of the bone ultimately producing significant instability and dislocations of adjacent joints [8]. At this point, a diagnosis of a Charcot neuroarthropathy (CN, Charcot foot) is often made. The CN most commonly results from diabetes mellitus, in western civilizations, but can also occur due to other etiologies [9, 10]. Although the specific cause is not completely understood, important causative factors have included repetitive overloading due to unrecognized trauma, poor bone quality due to metabolic changes, and local inflammatory changes with dysfunctional bone formation and resorption [9, 11, 12]. Additionally, acute fractures treated in a delayed manner can also trigger the onset of CN [13].

Sanders and Frykberg [14], observed a forefoot pattern in about 80 % of their patients, but recent studies have discussed a shift towards the ankle and hindfoot [15, 16]. This results in a high

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Fig. 7.1 Typical pathologic calcaneal and talar fracture patterns in diabetic patients: (**a**) Reverse oblique fracture through the anterior calcaneal process, (**b**) "beak" fracture of the calcaneal tuberosity. By definition, the subtalar joint is not involved. (**c**) Talar neck stress fracture in a diabetic patient with (**d**) massive edema. (from Zwipp H, Rammelt S. Tscherne Unfallchirurgie: Fuss. Berlin/Heidelberg/New York, Springer, 2014)

degree of instability that is difficult to manage with a cast or brace. These patients often have a dramatic decrease in quality of life and are at considerable risk for an amputation [10, 14]. Isolated, extra-articular calcaneal fractures are seen in only about 1–2 % of patients with diabetic arthropathy [16]. Acute fractures occur as one of three patterns: a fracture through the anterior calcaneal process, one that presents as a reverse oblique fracture through the tuberosity exiting anterior to the sinus tarsi, and a more frequent pattern that presents as a displaced avulsion fracture off of the superior portion of the tuberosity ("beak" fractures, Fig. 7.1) due to the pull of the Achilles tendon [17]. The latter fracture pattern is frequently associated with an increased risk of skin breakdown over the displaced fragment that can lead to a subsequent ulceration and the development of an infection [18].

Studies have shown that the presence of diabetes mellitus is a risk factor for the development of wound complications and infection in acute hindfoot fractures (Fig. 7.2). Folk et al. [19] found a 2.8-fold increased infection rate in diabetic patients with acute calcaneal fractures. More recently, Ding et al. [20] calculated an odds ratio of 6.23 for diabetes mellitus as a risk factor for postoperative wound complications while Wukich et al. [21] found a fivefold increase in postoperative infection rates in persons with

Fig. 7.2 Extensive wound edge necrosis after plate fixation via an extensile lateral approach for a displaced intra-articular calcaneal fracture in a 72-year-old patient with insulin-dependent diabetes mellitus

diabetes compared to non-diabetics. In the latter study, the presence of complicated diabetes increased the risk of postoperative infection by a factor of ten, compared with non-diabetics, and by a risk factor of six when compared to patients with uncomplicated diabetes. Interestingly, there was not much difference of developing a postoperative infection when non-diabetics were compared to patients with uncomplicated diabetes.

Another complication associated with diabetes is that the time to fracture healing is often prolonged, especially with poorly controlled diabetes [22]. However, in the absence of manifest neuropathy, vasculopathy or nephropathy, similar results as in non-diabetic patients can be expected after internal fixation, provided that the patients' blood glucose levels are well controlled and that prolonged offloading can be ensured in compliant patients [7, 13]. Lastly, bony issues have also been noted after performing primary or secondary fusions of the hindfoot. As noted with fracture healing, in the presence of abnormally high glucose levels, and despite adequate surgical technique, patients will demonstrate increased rates of delayed and non-union of the fusion mass [23]. Acute fractures of the talus or CN involving the talus and peritalar joints can also occur producing significant instability of Chopart's, the subtalar and the tibiotalar joints. Further information regarding classifications can be obtained in Chap. 4.

Treatment Recommendations

The goals for the management of these patients, is to protect the foot, minimize soft-tissue breakdown and ulcerations, and to keep the patient as normally ambulatory as possible. However, the literature on the management of acute hindfoot fractures in diabetic patients is scarce and no controlled studies are available. From the available previously cited sources, discussions with colleagues and the author's own experience [7] some guidelines can be offered when considering the surgical management of these injuries.

In compliant patients with well-controlled diabetes ($HbA_{1C} < 6.5$), and without neuropathy, angiopathy, or nephropathy, a standard open reduction and internal fixation may be carried out. Due to potential healing problems, it is recommended that blood glucose levels be kept within normal limits throughout the time of healing.

In patients with poorly controlled diabetes ($HbA_{1C} > 6.5$), poor or non-compliance, along with manifest complications of neuropathy, angiopathy, or nephropathy, no extensile approaches should be used due to a compromised immune system along with an impaired wound and bone healing. Patients presenting with open fractures should still undergo an urgent irrigation and debridement. In the presence of grossly displaced fractures and fracture-dislocations, the author's recommendation is to use minimal incisions that allow fixation to be performed either percutaneously or augmented with external fixation. Once healing has occurred, the presence of any symptomatic arthritis can be managed electively with an arthrodesis, without the need for an extensile approach.

Patients presenting with acute neuropathic talus or calcaneus fractures, impeding CN, or an unstable hindfoot should not be managed with standard internal fixation since it will invariably fail because of poor bone quality, impaired healing potential, impaired proprioception and loss of sensation that makes offloading of the foot by the patient unpredictable. For most neuropathic fractures, immobilization and offloading in a well-padded cast is the first line of treatment.

This treatment might even lead to a full restitution in case of early neuropathic changes, i.e., stress fractures that are detected as bone marrow edema on the MRI [7, 8, 16]. Any grossly displaced or unstable hindfoot fractures or fracture-dislocations (combination of Sanders Frykberg Types IV and V) that are not amenable to bracing should be treated with a hindfoot fusion using internal and/or external fixation. In these highly unstable conditions, an acute fusion at the time of presentation, which usually is not the time of injury, will also help transforming them into a more stable Eichenholtz stage while bracing will only maintain the vicious circle of chronic instability and thus progression of the disease [7, 24, 25].

Chronic ulcerations and bony prominences leading to skin necrosis also have to be debrided according to the individual pattern of deformity. Isolated exostectomy and ulcer debridement with primary or secondary wound healing will only be successful in cases of minor deformities. When associated with major deformities and/or gross instabilities, only surgical treatment of these underlying pathologies will eventually result in ulcer healing. In recalcitrant or chronic ulcerations that fail conservative approaches and are associated with osteomyelitis of the calcaneus, a partial or total calcanectomy remains a salvage option. However, this may lead to a significant functional impairment due to an alteration of the overall foot mechanics [26, 27]. In cases of otherwise intractable infections one may have to consider an ankle disarticulation (Syme's amputation) or below knee amputation as a salvage procedure. Specific treatments will be described in this chapter.

Non-Operative Treatment

The use of non-operative management for talar and calcaneal fractures should be considered in all patients who present with non-displaced fractures. Additionally, any patient presenting with poorly controlled diabetes ($HbA_{1C} < 6.5$), poor compliance, neuropathy, angiopathy, or nephropathy, or fractures that will have a stable collapse (i.e., do not produce any bony prominence on the plantar surface of the foot) can be considered candidates for non-operative care in order to avoid the potential risks of surgery (Fig. 7.3). Minimally or non-displaced fractures of the calcaneus (Sanders Frykberg Type V) may be treated

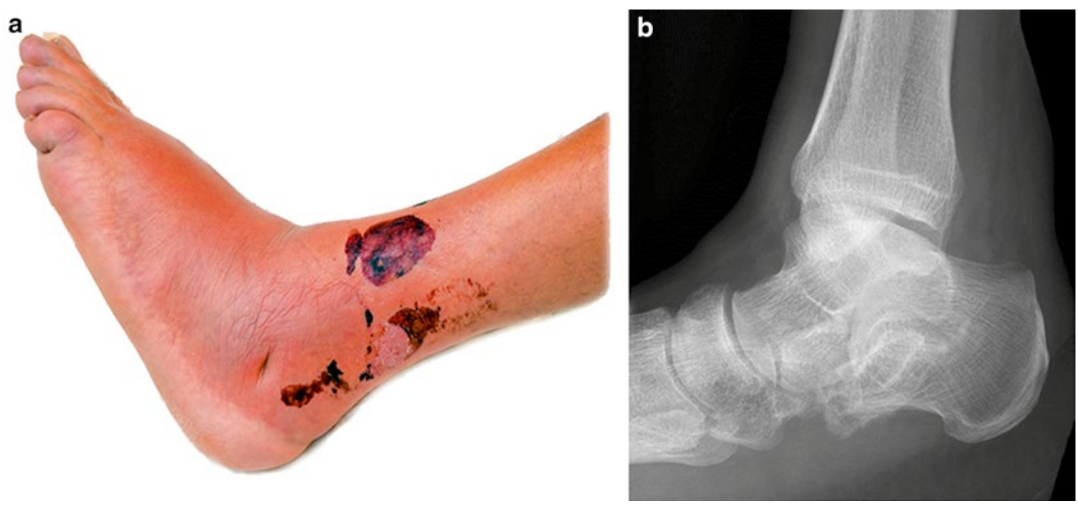

Fig. 7.3 (**a**, **b**) Prolonged soft-tissue swelling around the hindfoot in a 69-year-old patient with poorly controlled insulin-dependent diabetes mellitus and a displaced intra-articular calcaneal fracture without direct soft-tissue compromise. The skin blistures healed at 2 weeks. Non-operative treatment was initiated because of the significantly increased perioperative risk

Fig. 7.4 Acute neuropathic fracture of the calcaneus and talar head without gross displacement or soft tissue compromise in a 34-year-old female with severe, poorly controlled insulin-dependent diabetes. (**a**, **b**) The patient reported increasing pain and swelling over the heel after a misstep on a stair. The calcaneal fracture displays an oblique course with only marginal involvement of the subtalar joint, compatible with a Sanders/Frykberg Type V fracture pattern. Treatment consisted in offloading in a walker. After 3 months (**c**) the fracture has consolidated and soft-tissue swelling has subsided. (from Zwipp H, Rammelt S. Tscherne Unfallchirurgie: Fuss. Berlin/Heidelberg/New York, Springer, 2014)

with offloading in a cast or a cam walker boot for 6–12 weeks. In the author's experience, neuropathic talar fractures present either as stress fractures (see Figs. 7.1 and 7.4) or as progressive necrosis with gradual dissolution until there is a complete collapse ("disappearing talus," see Fig. 7.5). Patients with minimally or non-displaced fractures are restricted to non-weight-bearing in a well-padded below-knee cast until solid a fracture union is noted. Weight-bearing is then gradually increased after radiographic evidence of bone healing, usually beginning after 6–12 weeks. Alternatively, in compliant patients which adhere to non-weight-bearing, an orthotics cam walker boot may be used.

It is important that a coordinated team approach be used to manage these patients. This includes obtaining or continuing the medical treatment of their diabetes. Patients should also be informed that special foot care is mandatory in order to avoid deleterious complications, not only from the acute fracture but also from the sequelae of diabetes. Foot care should include special individually fitted shoewear with soft insoles.

Fig. 7.5 A 50-year-old male with insulin-dependent diabetes mellitus underwent hardware removal for residual pain 9 months after an acute ankle fracture that had healed with prolonged immobilization. (**a**, **b**) He presented 6 months later with increasing pain and deformity. (**c**, **d**) Radiographs and CT scans revealed a CN with destruction of the subtalar joint. (**e**) Because of the high degree of instability, the hindfoot was stabilized with a curved retrograde nail (**f**)

Standard Operative Treatment

Any patient presenting with an open fracture should be managed the same as any non-diabetic patient presenting with an open fracture. This includes emergent or urgent debridement and irrigation, repeated every 48–72 h as needed, the early use of broad spectrum intravenous antibiotics, dispensing tetanus prophylaxis and closure of the wound or providing coverage as soon as possible. Grossly displaced closed fractures and fracture-dislocations that threaten the skin should be reduced as soon as possible using minimal incisions and fixed either percutaneously with screws and/or with the use of an external fixator. Pinning with K-wires is not encouraged as they do not provide adequate stability and constitute a potential source of infection. Definitive fixation is performed in a staged manner after soft-tissue consolidation. As previously stated, a standard open reduction and internal fixation without crossing any joint can be considered for compliant patients who present with acute talar and calcaneal fractures that have an HbA_{1c} less than 6.5, are able to sense a 5.07 or smaller Semmes-Weinstein monofilament, have palpable foot pulses, do not have osteoporotic bone, and are without any manifestations of autonomic dysfunction.

If these criteria are met, displaced talar fractures should be reduced and fixed with screws and/or small plates using the classical two-incision approach, with or without the addition of a posterior approach, depending on the individual fracture anatomy as evaluated by preoperative CT scans [1, 7]. Postoperatively, the patients are restricted to partial weight-bearing with 20 kg or less, which is equivalent to the foot just touching the ground without loading, in a cast or walker for 10–12 weeks until bony union.

Displaced, intra-articular calcaneal fractures are usually treated according to the individual fracture pattern using either locking plate fixation via an extended lateral approach (Fig. 7.6) or, if possible, screw fixation via a minimally invasive approach [2, 3, 28]. The latter is often a good option for simple fracture patterns like tongue-type fractures with large or easily accessible articular fragments (Fig. 7.7). Meticulous handling of the soft tissues is of utmost importance in these cases. Additionally, patients have to be told about the possibility of increased risk of infection and increased time to union. The postoperative regimen has to be tailored to the individual course, with repeated clinical follow-up. The author's preference is to mobilize patients into their own shoe with weight-bearing restricted to a maximum of 20 kg until radiographic evidence of bone healing, usually identified after 8–10 weeks. Over the whole course of treatment the serum glucose levels have to be controlled tightly and kept within normal limits in order to avoid complications. With careful soft-tissue handling, anatomic fracture reduction, and adequate follow-up, similar results can be expected as seen in non-diabetic patients.

Late Arthrodesis

Regardless of whether patients are treated operatively or non-operatively, the sequelae of posttraumatic arthritis may develop. However, prior to undertaking any arthrodesis, any patient presenting with a chronic infection should first undergo serial debridements and then be managed by external fixation or staged internal fixation, and intravenous or oral antibiotics, until they appear clinically clean.

In the presence of symptomatic arthritis, an arthrodesis may be carried out on consolidated fractures via less extensile approaches. With poor skin conditions, percutaneous, arthroscopically assisted arthrodesis techniques may be employed both at the ankle and subtalar joint as they have similar fusion rates as open techniques [29]. Compression may also be obtained using a hybrid wire, hexapod, or Charnley external fixation frame. If an external device is employed it is important that the pin sites be cleaned on a regular basis and the fixators inspected for pin track infections. If a pin tract infection develops either new and separate pins and site are exchanged or the entire frame has to be removed and treatment continues in a cast. If the need arises for an ankle fusion, this can be preformed either with screws alone or in combination with plates while retrograde nailing may offer the best stability for a tibiotalocalcaneal fusion [24, 25, 30].

For malunited calcaneal fractures with posttraumatic subtalar arthritis, the author's preferred approach is a subtalar fusion performed with the patient placed into a prone position using a straight posterolateral approach [5]. This approach is much less prone to complications than a standard extensile lateral approach to the calcaneus. It furthermore allows adequate visualization and lengthening of the collapsed heel with a bone block distraction arthrodesis in patients with good bone stock (Fig. 7.8). Diabetic patients who present with malunited talar fractures or patients who develop avascular necrosis of the talar body with subsequent collapse often require a tibiotalocalcaneal fusion for a salvage of the hindfoot [5, 30, 31].

Patients undergoing an arthrodesis must be followed closely with radiographic examinations every 6 weeks. It has to be borne in mind that in the presence of diabetes, prolonged times to bone healing have to be expected not only for acute fractures but also for fusions about the foot and ankle [22, 23]. There is poor evidence for the efficacy of additional measures like the use of a

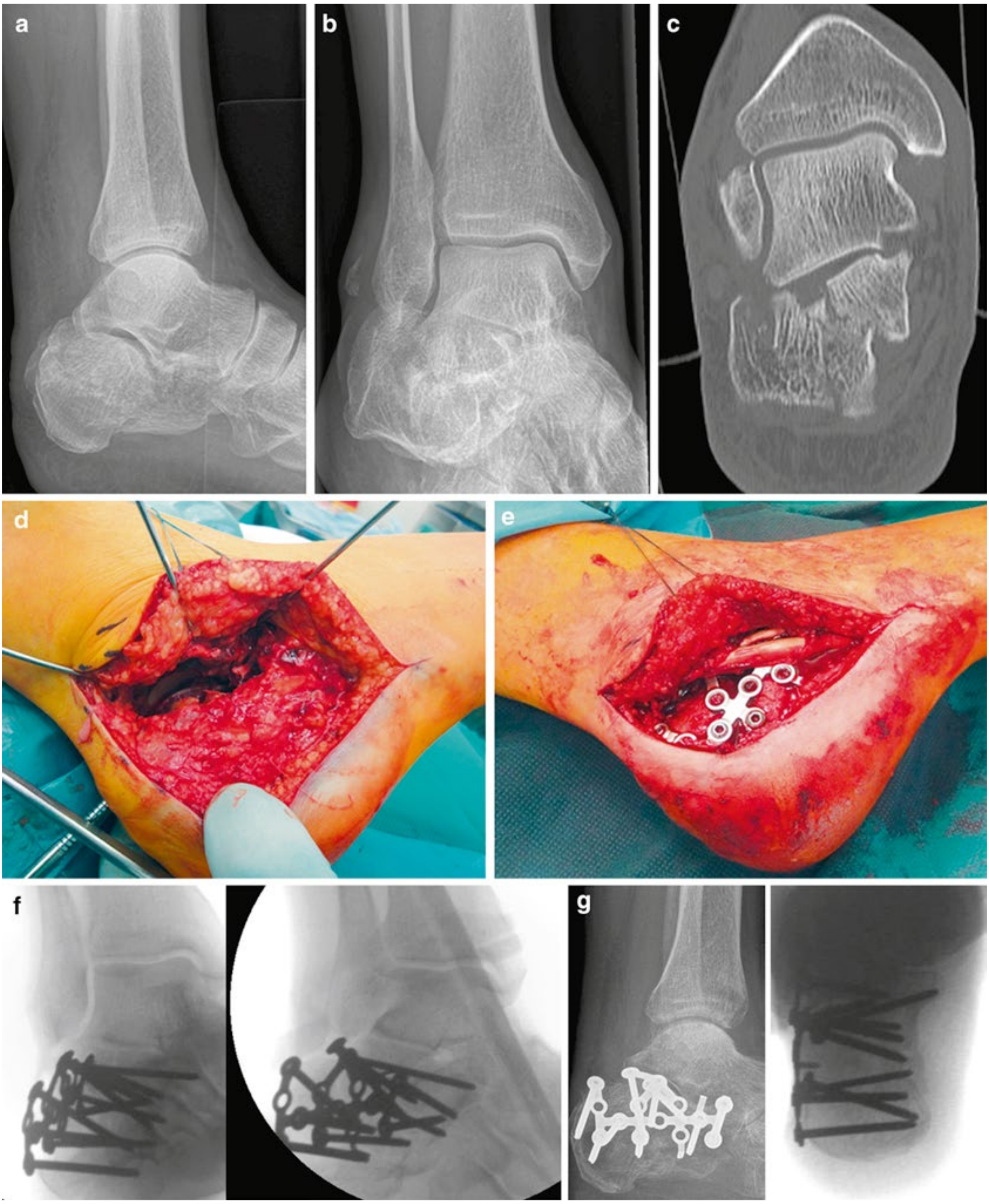

Fig. 7.6 (**a**–**c**) Displaced intra-articular calcaneal fracture with excessive broadening of the heel, peroneal tendon dislocation (note the bony avulsion of the superior peroneal retinacle) and two displaced fracture lines in the subtalar joint (Sanders type III) in a 53-year-old male patient with well-controlled diabetes. (**d**, **e**) Treatment consisted of a standard open reduction and internal fixation, via an extensile lateral approach, with reconstruction of the joint and the calcaneus. The epiperiosteal full-thickness soft-tissue flap is held by a suture and gently retracted with K-wires placed into the lateral talar process. No sharp retractors were employed. The peroneal tendons were reduced after fixation of the calcaneus with the torn retinaculum reattached to the tip of the fibula. (**f**, **g**) Intraoperative fluoroscopic images and postoperative radiographs showing anatomical reduction of the joint and the calcaneal shape. The soft tissues healed uneventfully

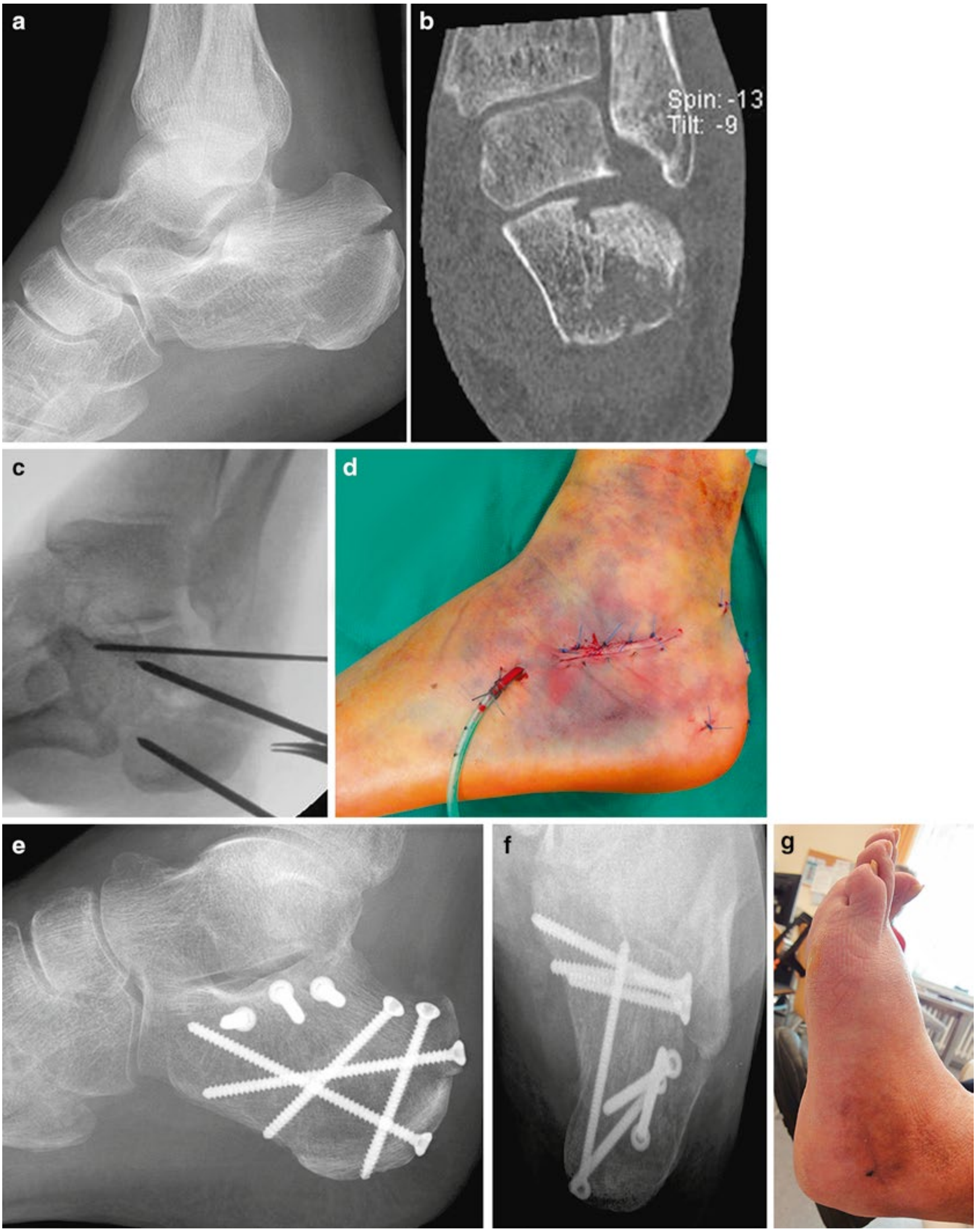

Fig. 7.7 (**a**–**c**) Minimally invasive fixation of an acute calcaneal fracture with a single displaced lateral fragment in the posterior facet of a 72-year-old patient with well-controlled diabetes mellitus. Anatomic reduction of the joint is verified with fluoroscopy using a small sinus tarsi approach. (**d**–**f**) Screws were introduced through small incisions or percutaneously. (**g**) Six weeks after the surgery, the soft tissues have healed uneventfully

Fig. 7.8 A diabetic patient (the same as in Fig. 7.3) with painful subtalar arthritis 3 months after sustaining a displaced intra-articular fracture. (**a**, **b**) A subtalar fusion was performed using a posterolateral (Gallie) approach. (**c**) CT scanning at 6 months shows good incorporation of the bone block. The soft tissues healed uneventfully

bone stimulator. Rather, in these patients the blood glucose levels should be controlled and in the presence of manifest osteoporosis, specific treatment should be used [9, 21, 23].

Management of Neuropathic (Charcot) Fractures

Treatment of diabetic CN of the hindfoot is directed towards achieving a stable plantigrade foot that is free of infection or ulceration and allows the patient to ambulate in an orthopedic shoe [7, 10]. Realignment and stable fixation is important in order to break the vicious circle of instability and bone resorption [12, 32, 33]. The distinction between acute traumatic fractures and those presenting with fractures associated with CN is that the latter often present with neuropathy (i.e., inability to sense a 5.07 Semmes-Weinstein monofilament), no history of trauma, have noticed more swelling of the foot than usual making it difficult to place their foot into a shoe, possess signs of autonomic dysfunction (dry, scaled, and reddened skin with diffuse edema of the extremity), have unusual fracture patterns, may or may not have pain, and often have late rather than acute presentations. However, is important to remember, that an acute fracture can also trigger the onset of CN of the hindfoot (Fig. 7.5).

Traditionally, these patients are managed non-operatively with prolonged offloading and immobilization of the affected foot in a total contact cast (TCC). The cast is applied and patients are completely offloaded for a minimum of 6 weeks or until radiographic signs of bony consolidation are seen. Patients are then placed into a special boot or walker (like an ankle foot orthosis, AFO, or a Charcot restraint orthotic walker, CROW). Patients are instructed that they will require individually fitted orthopedic shoes and regular foot care for the rest of their lives in order to avoid deleterious consequences like gross instability, undetected lesions, plantar ulcerations, and subsequent infections with the potential need for amputation.

Surgery is usually reserved for highly unstable, non-braceable deformities and in patients with non-healing ulcers or deep infections [14, 34]. Unfortunately, CN of the ankle/hindfoot type regularly results in severe deformity and instability that does not respond well to casting [7, 16]. Moreover, non-operative treatment in a cast often requires long periods of immobilization and failure rates approach 40 % even in the best of hands [35, 36]. In addition, patients with CN frequently have a poor compliance and difficulties controlling the amount of weight-bearing because of altered pain perception, proprioceptive difficulties and gait disturbance resulting from systemic neuropathy [11]. Consequently, implants have to withstand high loads which may cause implant failure.

Several classifications exist for the lesions at the foot and ankle in CN [10, 15, 16]. The classification most often used by the author is described by Sanders and Frykberg [14] and refers to the anatomical site of the arthropathy. Type I describes a lesion at the forefoot, type II at the tarsometatarsal joint, type III at the mid-tarsal joint, type IV at the hindfoot, i.e., ankle and subtalar joint, and type V extra-articular lesions at the calcaneus. However, neuropathic deformities can occur at several sites at once, therefore combinations of these types are frequently seen. This chapter deals specifically with hindfoot fractures, i.e., Sanders/Frykberg types IV and V.

Sanders/Frykberg Type IV Pattern (Ankle/Hindfoot)

Grossly displaced and unstable hindfoot fracture-dislocations (Sanders Frykberg type IV) that are not amenable to bracing should be treated with a hindfoot fusion technique using internal or external fixation. Advantages of using an external fixation are the low amount of implant mass within the bone, the ability to avoid any medullary reaming, the use of small incisions, and the possibility of stepwise reduction of gross deformities. Disadvantages are high rates of pin track infections and the relatively low biomechanical stability compared to internal fixation methods [25, 35].

Biomechanically, retrograde intramedullary nailing (Fig. 7.5) provides the most stable fixation available [30]. The complication rates following hindfoot fusion with retrograde nailing are significantly higher in patients with CN than for patients presenting with hindfoot arthritis or deformities of other origins [24]. The reported rates of limb salvage range between 86.7 and 100 %, and fusion rates between 77 and 95 % [24, 37, 38]. The use of curved nails provides more bony purchase within the calcaneus [30, 38]. Stability can be further enhanced with the use of a spiral blade within the calcaneus (see Fig. 7.5) and multiple locking screws within the nail.

Sanders/Frykberg Type V Pattern (Calcaneus)

Rarely, does CN develop in the hindfoot as an isolated entity. It is estimated that approximately 1 % of all CN fractures occur in the calcaneus (Sanders Frykberg Type V). By definition, these do not involve the subtalar joint (Figs. 7.1 and 7.6). The majority of these fractures may be treated with offloading in a cast or walker for 6–12 weeks (Fig. 7.4). Chronic ulcerations and bony prominences leading to skin necrosis have to be debrided according to the individual pattern of deformity. Of particular challenge is an acute calcaneal fracture that presents with an ulceration of the heel. However, good outcomes can be obtained with complete healing of both the fracture and ulceration after serial deep debridements and a prolonged course of offloading in a TCC has been used (Fig. 7.9). Patients are seen on an outpatient basis at least once a week until complete wound healing. After soft-tissue and bone consolidation, weight-bearing is gradually increased in a special boot or walker, depending on the patient's compliance.

Using conventional internal fixation for the treatment of these patients will invariably be prone to failure. Implants usually fail and lead to further bony and soft-tissue complications (Fig. 7.10). In the author's opinion, in the presence of CN only open calcaneal fractures or grossly displaced fractures with severe deformity of the hindfoot and direct compromise to the soft tissues should be treated operatively. Depending on the size of the fragments fixation may be obtained using combinations of short plates, screws, tension band wiring, or suture anchors [28, 39]. Most fractures are extra-articular, and involve the posterior tuberosity of the calcaneus. This allows fixation to be achieved using minimal incisions or with percutaneously placed screws. Because the Sanders/Frykberg type V lesions are either completely extra-articular or only marginally involve the subtalar joint, additional joint trans-articular fixation or fusion is usually not needed. Rather, these additional procedures only add to surgical trauma and are prone to complications like infection or nonunion of the attempted arthrodesis [21, 23]. Alternatively, a small or fragile posterior tuberosity fragment may be excised and the Achilles tendon reattached to the calcaneus if it inserted on the fragment. In case of an open fracture, the decision to partially or totally resect a fractured fragment can be made in order to achieve wound closure without any tension on the wound edges.

Amputations

The risk of soft-tissue and bone infection after talar and calcaneal fractures is significantly increased in diabetic patients with poorly controlled blood glucose levels and complications such as neuropathy [19–21, 28]. Chronic osteomyelitis that develops after an acute hindfoot fracture, which does not respond to serial debridements and antibiotic therapy, may require a partial

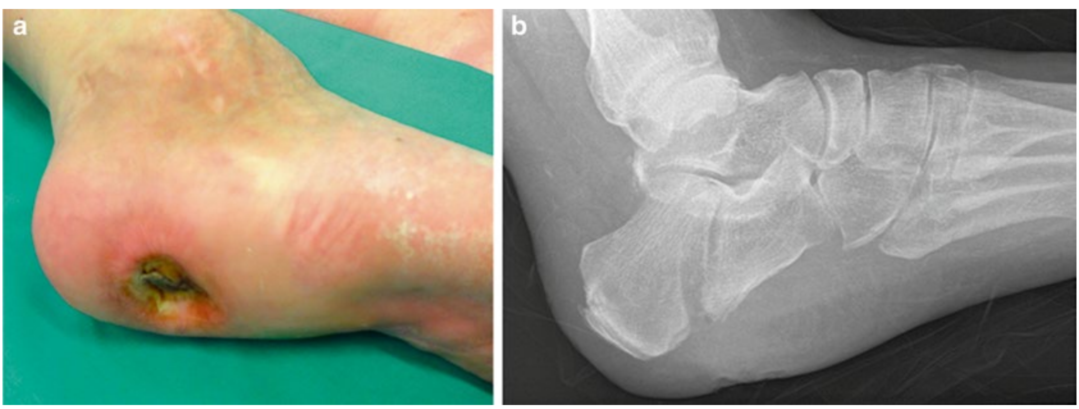

Fig. 7.9 A 65-year-old insensate male presents with acute bleeding from a chronic ulcer below the calcaneal tuberosity. (**a**) He reported hearing a "crack" when standing up in the morning. (**b**) The acute neuropathic fracture displays the typical reverse oblique course without involvement of the subtalar joint but in direct continuity with the heel ulcer. (**c**) Note the air bubbles at the fracture site in the CT scan as a sign for an open fracture. (**d**) An MRI shows the surrounding edema and the absence of diffuse bone infection. (**e**) Treatment consisted of serial local debridements, temporary insertion of an antibiotic bead, and application of antiseptic dressings. (**f**, **g**) Complete offloading of the heel in a well-padded total contact cast was used for 3 months. (**h**, **i**) After a prolonged course both the fracture and the ulceration healed completely. Afterwards, the patient was treated with orthopedic shoewear

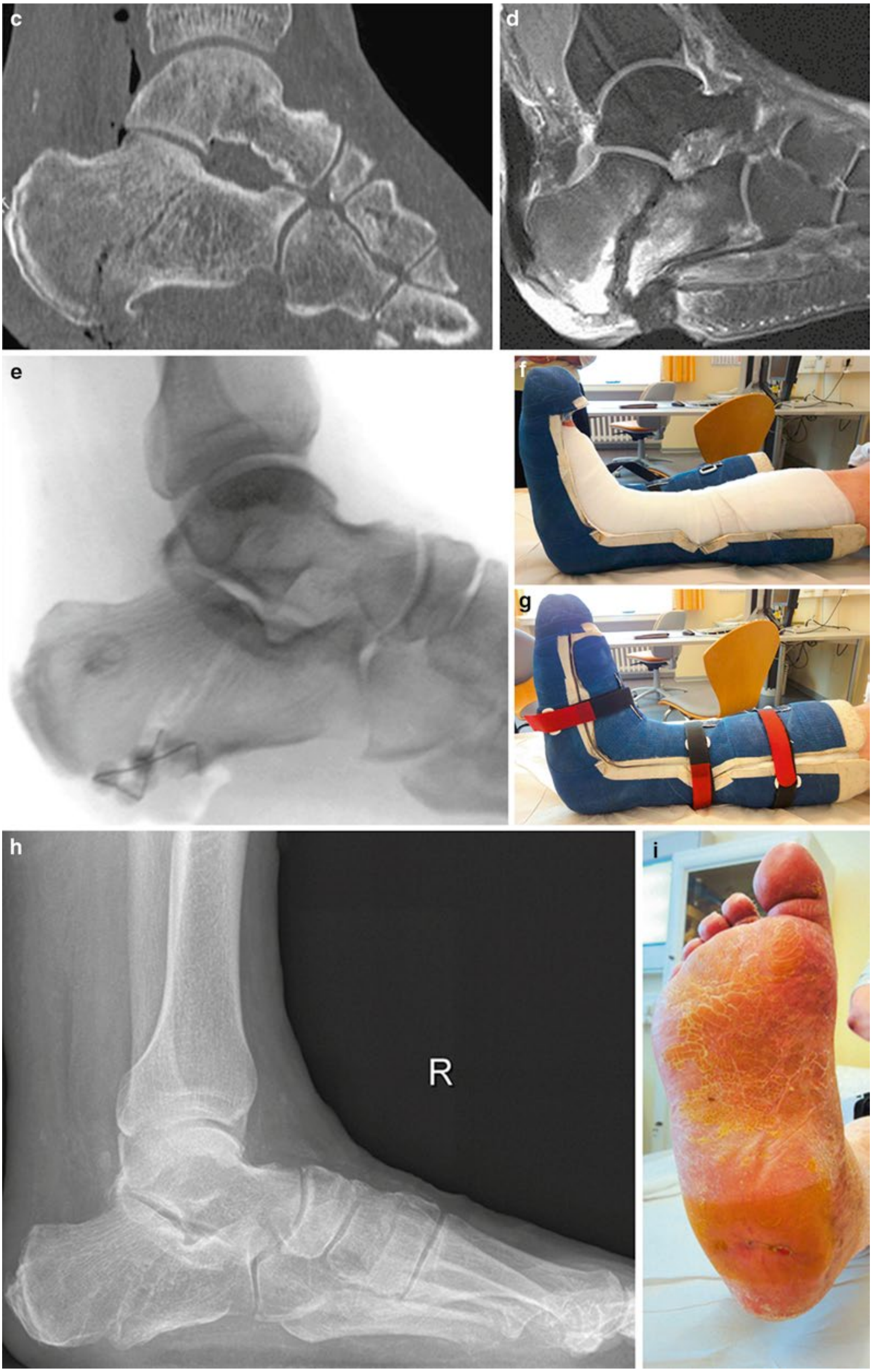

Fig. 7.9 (continued)

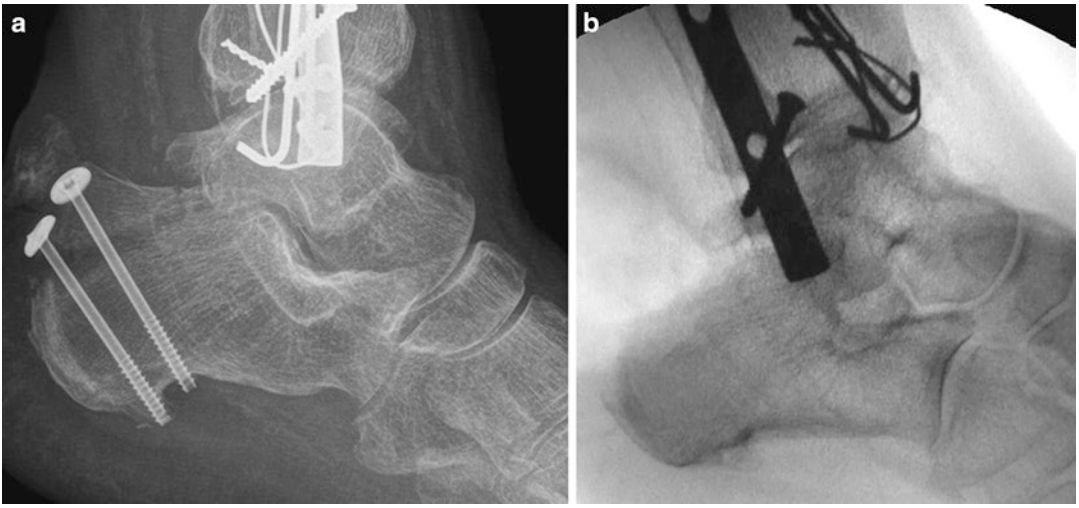

Fig. 7.10 A 59-year-old female patient with insulin-dependent diabetes had been treated with open reduction and screw fixation for a neuropathic calcaneal fracture. (**a**) She presented with a full thickness skin necrosis over the posterior tuberosity because of a non-union and complete redislocation of the fracture due to the pull of the Achilles tendon. Treatment consisted in resection of the displaced fragment and repeated debridements until soft-tissue closure became possible (**b**)

or total amputation at the ankle and hindfoot. In-lieu of a complete amputation, some "internal" amputations, (i.e., a partial resection of the bone) can be pursued in order to save the integrity of the limb but at times at the cost of considerable loss of function [40]. At the hindfoot, an astragalectomy may also be performed for septic necrosis of the talus [5, 41]. The talar head should be preserved, if it is not affected by necrosis and infection, in order to preserve some motion at the midfoot level [1]. The first step is that all the necrotic or infected bone is resected and an antibiotic bead or cement spacer is introduced into the resulting cavity. An ankle spanning external fixator is applied for temporary stabilization. When the infection has resolved, which may require further debridements, the spacer is replaced by a bulk allograft or corticocancellous bone graft from the iliac crest. Patients with manifest CN often present with threatening or manifest ulceration over the lateral or medial malleolus. In these cases a direct tibiocalcaneal fusion is performed in order to allow bone healing and direct closure of the soft tissues. Fixation is achieved with interlocking plates and screws, intramedullary nailing or compressing external fixation in the form of a Charnley or small wire frame. Regardless of the method of fixation, care should be taken to use fluoroscopy during fixation to note that good axial alignment has been obtained in order to avoid placing the hindfoot into a varus or valgus position The remaining talar head is then attached to the bone graft or anterior part of the tibia if it is being preserved [1, 5].

Partial or total calcanectomy is a salvage option for chronic ulcerations of the heel that present with a diagnosis of calcaneal osteomyelitis [26, 27]. While this procedure may not lead to a perceived loss of integrity of the limb, for the patient it is often associated with significant functional impairment due to the loss of an important lever arm of the heel with the attachments of the Achilles tendon and plantar fascia (Fig. 7.11).

The classical amputation techniques at the ankle and hindfoot, such as Pirogoff (Fig. 7.12) and Syme amputation remain a valid salvage option that still allows the patients to walk on their own sole [40]. However, in cases of otherwise intractable infection, a below-knee amputation is often the best option for these patients.

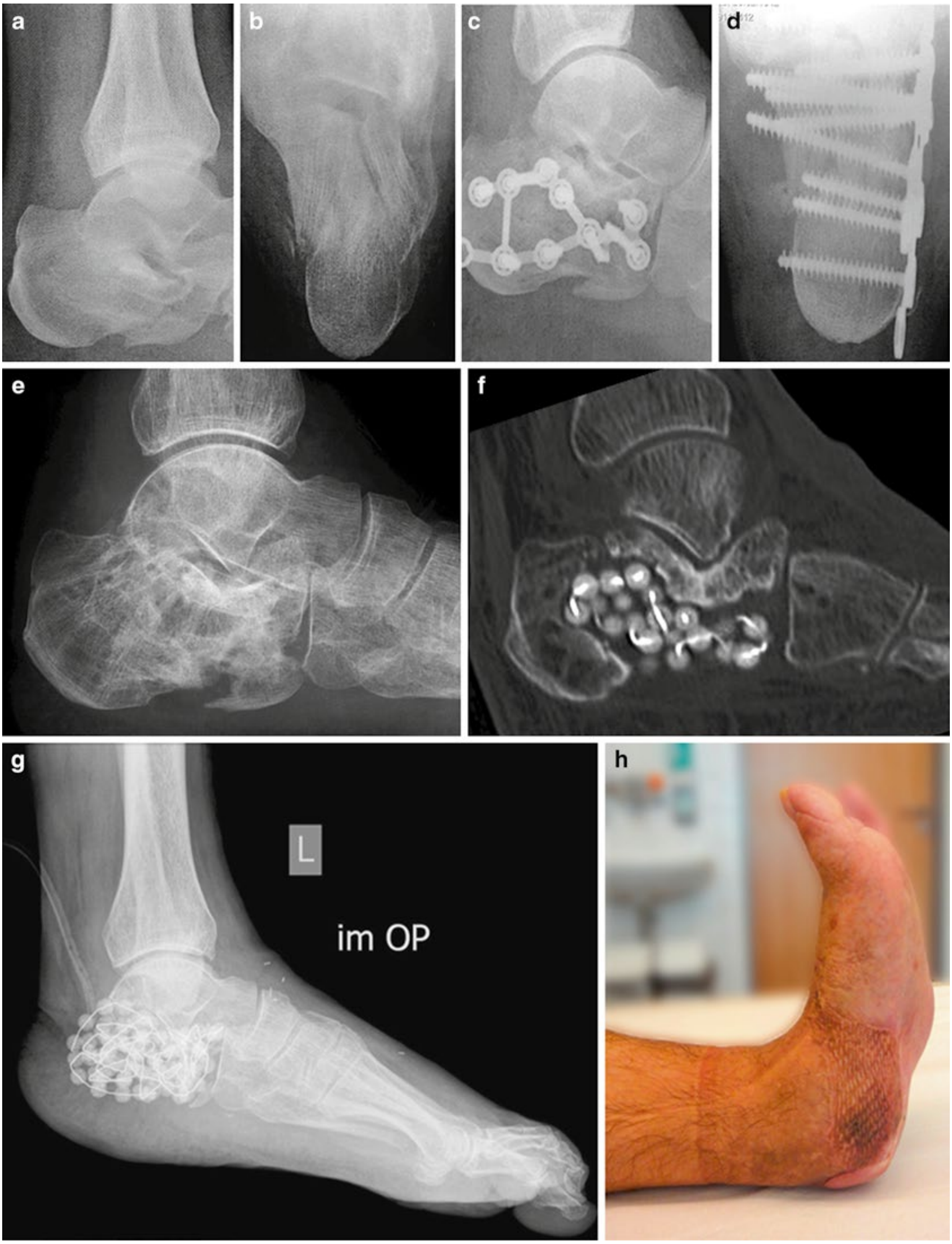

Fig. 7.11 (**a**, **b**) Lateral and axial views of a 65-year-old diabetic patient with poorly controlled diabetes presenting with a displaced, intr-articular calcaneal fracture. (**c**, **d**) Initial treatment consisted in lateral plate fixation via an extensile approach. Note the medially and laterally protruding implants and failure to restore calcaneal anatomy. (**e**, **f**) Despite early implant removal the patient developed chronic osteomyelitis of the calcaneus. Treatment consisted of repeat debridements and implantation of antibiotic beads. (**g**, **h**) A complete calcanectomy finally lead to a resolution of the infection but with considerable loss of function and shape

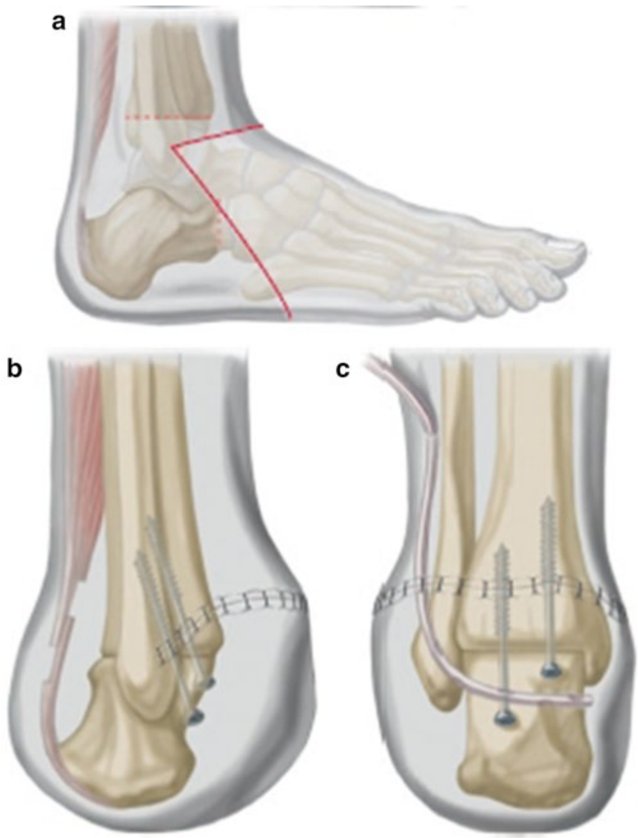

Fig. 7.12 Principle of the Pirogoff Amputation (Zwipp modification with minimal bone resection from the calcaneus at the anterior process resulting in only about 2–4 cm limb-length discrepancy). This amputation is useful for septic necrosis of the talus. For patients with CN, a more generous resection of the anterior part of the calcaneus is preferred in order to obtain soft-tissue and bone healing (**a**–**c**) (from: Rammelt S, Olbrich A, Zwipp H. Hindfoot amputations [German]. Operat Orthop Traumatol. 2011;23(4):265–79)

Summary

Acute fractures of the talus and calcaneus are challenging to treat. They are prone to complications in diabetic patients, above all those with poorly controlled blood glucose levels especially those with neuropathy. In the absence of an adequate trauma, a pathologic fracture has to be suspected when seen in patients with apparent CN. In compliant patients with well-controlled diabetes ($HbA_{1C} < 6.5$), and without neuropathy, angiopathy, or nephropathy, a standard open reduction and internal fixation may be carried out while blood glucose levels are kept within normal limits.

In patients with poorly controlled diabetes, poor or non-compliance, along with obvious complications, no extensile approaches should be used and non-operative treatment is preferred. Patients presenting with open fractures should still undergo an urgent irrigation and debridement. In the presence of grossly displaced fractures and fracture-dislocations, the author's recommendation is to use minimal incisions that allow fixation to be performed either percutaneously or augmented with external fixation. Symptomatic arthritis after both open and closed treatment can be managed electively with an arthrodesis after bone and soft-tissue healing, without the need for an extensile approach.

For most neuropathic fractures, immobilization and prolonged offloading in a well-padded cast is the first line of treatment. Any grossly displaced or unstable hindfoot fractures or fracture-dislocations (combination of Sanders Frykberg Types IV and V) that are not amenable to bracing should be treated with a hindfoot fusion using stable internal or external fixation. In cases of otherwise intractable infections one may have to consider a Pirogoff amputation or ankle disarticulation (Syme's amputation) or below-knee amputation as a salvage procedure.

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