Problems, Obstacles, and Complications of External Fixation in the Foot and Ankle

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Introduction

External fixation has been used in the foot and ankle for acute trauma, reconstruction, lengthening, and limb salvage techniques. Traditionally, internal fixation constructs have been thought to provide more reliable fixation and fusion rates [1]. However, more recent biomechanical studies have shown that similar stability can be obtained using external fixation compared to internal fixation (compression screws, intramedullary nail, etc.) [2–4]. The general consensus is that the use of external fixation is complex; however, the use of external fixation has many advantages due to the modularity and adjustability of the components both intraoperatively and postoperatively. Most forms of external fixation allow for immediate weight bearing during the postoperative course. The dynamic nature of many external fixation constructs allows for adjustments to be made outside of the operative room, including correction of residual deformities and augmenting compressive forces through fusion sites. External fixation can also be used as an adjuvant to soft tissue reconstruction. The use of external fixation allows patients earlier mobilization and the ability to better perform their activities of daily living during the treatment phase [5].

The use of external fixation can be complex and has been thought of as high risk with the potential for complications. Many factors can influence these issues, including surgeon experience, patient compliance, patient comorbidities, type of external fixation utilized, and indication for the use of external fixation. Complications can arise intraoperatively, postoperatively, and after frame removal. Paley published a standardized classification of difficulties that can arise during distraction osteogenesis for limb lengthening [6]. Many of these adverse results that occur during the treatment phase are not true complications, as they do not affect the final outcome. Therefore, adverse results associated with external fixation can be classified as problems, obstacles, and complications [6, 7].

Problems are defined as adverse results that are anticipated but resolved by the end of treatment without surgical intervention. Obstacles are defined as adverse results that require surgical intervention but resolved by the end of treatment. Complications can be local or systemic adverse events, and the resultant sequelae remain unresolved at the end of treatment. Complications can be further divided into minor and major. Minor complications are considered to be of little significance and do not interfere with the end goals of treatment. Major complications interfere with the end goals of treatment and can cause increased morbidity [6, 7].

Adverse results and complications in the use of external fixation include pin site infections, length of time in the external fixator, neurologic and/or vascular injury, thermal necrosis of bone during wire/pin insertion, increased amount of follow-up care, and the increased burden on staff and family caring for patients with external fixators. These complications can be more or less common depending on the type of external fixator construct utilized. The two types that will be discussed in this chapter include circular external fixation and monolateral external fixation. Indications for the use of external fixation are discussed in Table 30.1. Guidelines on the prevention and management of complications will be discussed, as well as techniques for building a stable external fixation construct will also be presented.

Complications of External Fixation: Pin Site Infections

Pin site infections are the most common complication of circular external fixation. It is important to maintain a stable construct throughout the course of treatment because loosening of

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Table 30.1 Indication for external fixation and conditions that external fixation can be of a distinct advantage in comparison to internal fixation

Indications for external fixation	Conditions treated with external fixation
• Nonunion/Malunion • Joint distraction • Callus distraction/ lengthening of bone • Off-loading of wound/flap • Osteotomy • Arthrodesis • Infection/Osteomyelitis • Soft tissue/skin contracture • Fracture	• Extensive scarring/contracture/burns • Previous infection • Osteopenia/osteoporosis • Charcot neuroarthropathy • Poor soft tissue quality • Large deformity • Open wounds • Patient unable to maintain non-weight bearing • Immune compromised host

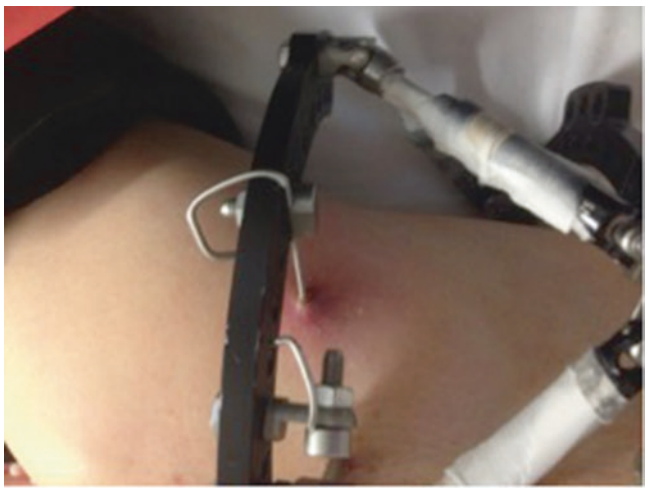

Fig. 30.1 Grade 1 pin site infection with soft tissue inflammation due to edema of the lower extremity. Treatment was successful with oral antibiotics and edema management (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

the fixation can lead to inflammation of the surrounding soft tissue. An unstable external fixator can result in a higher likelihood of a pin site infection. Paley developed a simple grading system for pin site associated problems: Grade 1, soft tissue inflammation (Fig. 30.1); Grade 2, soft tissue infection (Fig. 30.2); Grade 3, bone infection (Fig. 30.3) [6]. As long as Grade 1 and 2 problems are addressed (usually with a 10-day course of orally administered antibiotics), progression of serious infection to Grade 3 usually does not occur. The recalcitrant infections that infect a joint or have prominent cellulitis might require pin removal in the office or in the operating room, with additional wire placement as needed to maintain stability. Pin site infections that fail to respond to oral antibiotics should be treated with intravenous antibiotics. Prompt action is required to prevent premature removal secondary to deep infection.

Patients and their families should be well educated before and after the application of the fixator that infection may occur more than once during treatment. It is important to clean the pins with saline daily and keep them dry. The authors allow non-neuropathic patients to shower daily as long as attention is made to dry the pin sites thoroughly. Neuropathic patients have a higher likelihood of pin tract infections, and therefore as long as the pin sites are stable, we do not recommend showering or daily care. However, if the pin sites become inflamed, infected and/or draining, we recommend daily saline cleansing of the pin sites with Q-tips and wrapping gauze on the affected sites to stabilize the soft tissue. Oral antibiotics are prescribed for pin site infections, along with advising the patient to limit weight-bearing activity until the infection resolves. Persistent pin site infections are treated with removal of the affected pin/wire. If proper care is initiated immediately upon the discovery of a pin site infection, the progression to osteomyelitis is rare.

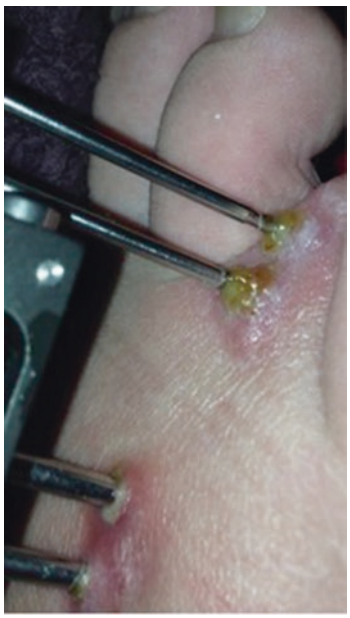

Fig. 30.2 Grade 2 pin site infection in a brachymetatarsia lengthening. Prompt pin care and oral antibiotics resolved this pin site infection (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Classification of Pin Site Infections

Problem—Pin site infection requiring removal of the half-pin or wire in the office and treatment with wound care and orally administered antibiotics.

Obstacle—Pin site infection requiring removal of the half-pin or wire and addition of a new half-pin performed in the operating room.

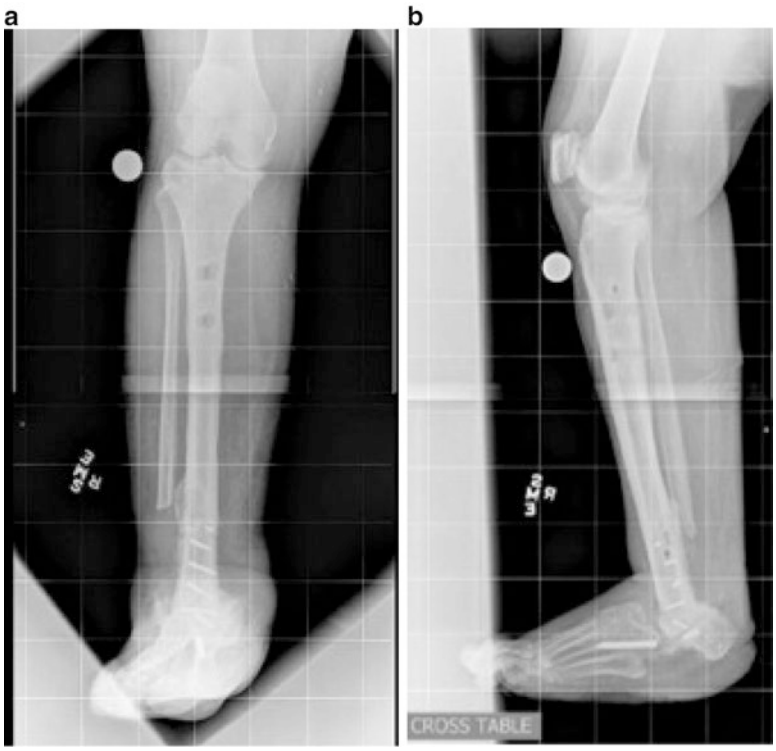

Fig. 30.3 Grade 3 pin site infection with radiographic evidence of proximal half-pin loosening and osteomyelitis formation in a neuropathic patient undergoing calcaneal-tibial arthrodesis for limb salvage (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Complication—Bone infection resulting from pin or wire site infection. Treatment of osteomyelitis consists of bone debridement and intravenously administered antibiotics.

Nerve and Vascular Injury

Injury to the major nerves and vessels of the lower extremity with the insertion of thin wire fixation and half-pin fixation is relatively rare. The surgeon must have intimate knowledge of the cross-sectional anatomy of the extremity and the safe zones for transosseous fixation. Nerve lesions manifest as pain in the anatomic distribution of the nerve. This is caused by nerve impingement from the percutaneous insertion of a wire or pin or during gradual deformity correction as a nerve becomes stretched or tethered. The best treatment is to remove the offending wire or pin and monitor the patient for improvement in symptoms. If symptoms do not improve, exploration of the nerve may be warranted.

Entrapment of the posterior tibial nerve can occur with external fixation during distal tibial/ankle deformity correction, especially when combined with lengthening. Prophylactic tarsal tunnel release should be considered for acute varus, equinus, or procurvatum ankle correction greater than 10° and gradual correction of deformity greater than 20° (Fig. 30.4) [8]. It is important to ensure complete decompression of the posterior tibial nerve, including the distal medial and lateral plantar nerve tunnels at the porta pedis. If tarsal tunnel decompression is not done prophylactically, it is important to monitor the patient closely for signs and symptoms of posterior tibial nerve entrapment postoperatively. Prompt intervention if symptoms arise will prevent irreversible nerve damage.

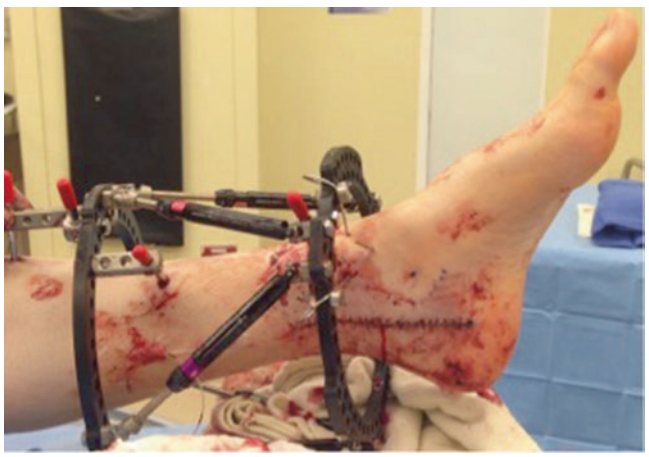

Fig. 30.4 Tarsal tunnel decompression performed prophylactically in a case of varus ankle deformity correction with ankle distraction. This was done prior to application of the multiplanar external fixator for correction of the deformity. Note the vertical nature of the incision so as not to disrupt healing during deformity correction (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Classification of Neurological Injury

Problem—Distraction and/or deformity correction results in numbness to the ankle/foot/toe. Decreasing the rate of correction allows the nerve compromise to resolve before the end of treatment.

Obstacle—Distraction results in numbness to the ankle/foot/toe; however, decreasing the rate of distraction does not resolve the numbness. Nerve decompression is then performed, and the nerve recovers before the end of treatment.

Complication—Intraoperative nerve injuries that result in slight numbness of the ankle/foot/toe but are not painful and do not affect the patient's function are minor complications. A major complication is a residual nerve insult that creates a neuropathic ankle/foot/toe that remains well after treatment and affects function.

Vascular injury is typically caused by a wire or pin introduced directly into a vessel. Bleeding will be noted with a vascular injury. The treatment is removal of the pin or wire and compression. Angiography may be necessary to determine what vessel has been injured and elucidate the sequelae. Edema throughout the treatment course is common as patients are often weight bearing as tolerated. To reduce edema, gauze is wrapped tightly around the pin sites between the skin and external fixator. Venous thromboembolism is uncommon in foot and ankle surgery; however, in patients with external fixation, proper prophylaxis should be considered based on the patient's risk factors.

Classification of Vascular Injury

Problem—Edema that is controlled with daily gauze wrapping. The daily gauze wrapping allows the edema to resolve before the end of treatment.

Obstacle—Vascular insult because of a misplaced pin/wire. The offending pin/wire should be removed and adjusted during a second surgery, which will allow the vascular insult to repair. This obstacle resolves before the end of treatment.

Complication—Non-repairable intraoperative vascular insult that affects vascularity to the foot is a minor complication. Intraoperative vascular insult, deep vein thrombosis, pulmonary embolism, and compartment syndrome are major complications.

Thermal Necrosis

Prevention of thermal necrosis is extremely important when placing wires and pins. Techniques used to reduce thermal necrosis include predrilling for half-pins and inserting by hand, use of sharp and non-cannulated drill bits, use of "on-off" drilling technique of pins and wires, tapping the wire through the soft tissues, deflation of the tourniquet to allow blood flow to cool the wires, and use of saline irrigation around the wires/pins during insertion. All cortical wires should be avoided due to rapid generation of heat during drilling. The prevention of thermal necrosis is vital because this can potentially lead to a stress riser and stress fracture in the bone or place the site at increased risk for developing later infection due to formation of a ring sequestrum.

Classification of Thermal Necrosis

Problem—Dense bone is noted during predrilling of half-pin. The drill bit is removed and flutes are cleaned. Drilling is continued with "on-off" technique to prevent further heat generation.

Obstacle—Pin/wire becomes loose postoperatively due to bone resorption from thermal necrosis. Pin/wire should be removed and replaced in a second surgery.

Complication—Thermal necrosis during pin insertion results in loosening of pin and forms a sequestrum leading to osteomyelitis. This is a minor complication if treatment leads to resolution prior to end of treatment. This is a major complication if it remains after treatment ends.

Stress Fractures/Fractures

Stress fractures and fractures can occur during treatment or following frame removal. The use of half-pins in neuropathic patients can increase the risk of this complication [9]. If this occurs during the treatment course, it is necessary to return to the operating room to extend the frame or increase the stability of the external fixation (Fig. 30.5). If this occurs following frame removal and the fracture is non-displaced, cast immobilization can be utilized. Most often, this does not affect the final result as long as the fracture heals. However,

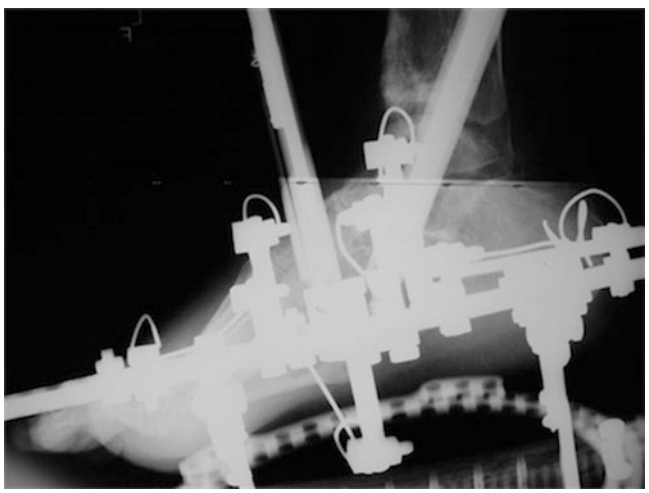

Fig. 30.5 Tibial diaphyseal fracture in a neuropathic patient (**a**), which required modification of external fixator for reduction and stabilization (**b**) (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

it is important to adhere to proper principles of building a stable frame to reduce the stress placed on the lower extremity. The authors recommend the use of all wire fixation and avoiding fixation in the isthmus of the tibia in patients whenever possible. The tibial ring block fixation should be utilized to diminish the amount of stress placed on the fixation.

Classification of Stress Fracture/Fracture

Problem—Intraoperative stress fracture/fracture noted. Frame bridged across the fracture to stabilize.

Obstacle—Postoperative stress fracture/fracture necessitates return to surgery for modification of frame to bridge and stabilize fracture. Fracture healing does not prolong treatment course.

Complication—Stress fracture/fracture after removal of external fixator that necessitates return to surgery for fixation or further immobilization in cast. This is a minor complication if the fracture heals without residual functional loss. This is a major complication if results in residual deformity or loss of function.

Joint Subluxation

Subluxation or dislocation of the ankle joint or metatarsophalangeal (MTP) joint can be seen with gradual correction of ankle equinus (Fig. 30.6) and gradual lengthening of the metatarsals for brachymetatarsia, respectively. This adverse result is due to preexisting muscle imbalance, joint incongruity, or improper external fixation construct. In order to prevent joint subluxation/dislocation, it is important to plan for this preoperatively.

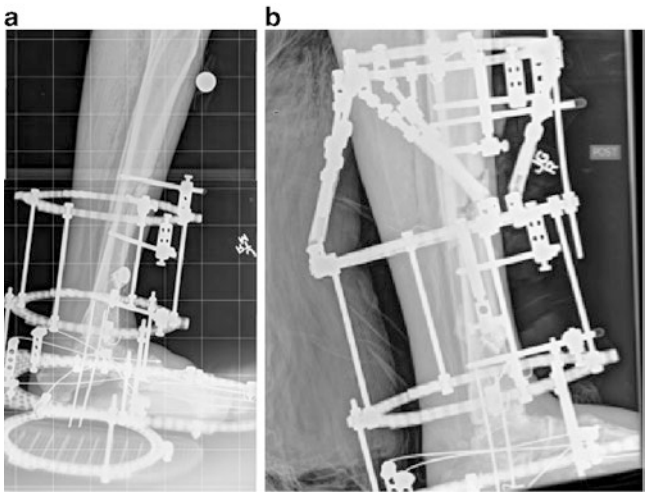

Fig. 30.6 Anterior ankle subluxation during gradual equinus correction requires modification of the axis of correction or insertion of additional talar fixation (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Correctly applying hinges at the axis of ankle joint motion and using two points of fixation in the talus will maintain ankle joint congruity while gradually correcting for equinus deformity. Relocation of the MTP joint and bridging of the external fixator across the MTP joint to the digit allows for maintenance of alignment during lengthening of the metatarsal. Pinning of the MTP joint with a Kirschner wire to maintain alignment has also been described, but in our experience, this causes a great amount of joint stiffness once the pin is removed. Treatment options for joint subluxation include physiotherapy, splinting, adjustment/modification of external fixation, revision surgery, decreasing the distraction rate, and isolated capsular release [7].

Classification of Joint Subluxation

Problem—Joint subluxation caused by rapid lengthening or correction of deformity. Decreasing the rate of distraction allows the tendon/capsule to elongate to resolve the joint subluxation.

Obstacle—Joint subluxation requiring modification or extension of the external fixation to relocate the subluxed joint and prevent recurrence. The subluxation resolves before the end of treatment.

Complication—Irreducible subluxation/dislocation of the joint after removal of the external fixator. This is a minor complication if the dislocation can be resolved with physical therapy. This is a major complication if residual subluxation creates pain and the foot/ankle loses function as compared with the preoperative function.

Length of Treatment

The length of time spent in the external fixator depends primarily on the indication for which it is used. In the case of acute trauma, the length of time can be a few weeks to a month if it is used as a temporary bridge to internal fixation. If circular or monolateral external fixation is used as the primary form of fixation, fracture healing, osteotomy, and soft tissue correction of any residual deformity determine the length of time in the fixator. Once there is evidence of healing of three cortices and the patient is clinically asymptomatic, the frame can be reduced in stiffness and subsequently removed. The principle of three cortices of healing works well in the long bones (i.e., tibia and femur); however, in the foot (i.e., metatarsals), this is more difficult to ascertain due to the superimposition of the metatarsals on a lateral radiograph.

Circular external fixation used for foot and/or ankle reconstruction or deformity correction has a much longer length of treatment. It is not uncommon for patients to have their fixator in place for up to three to six months or

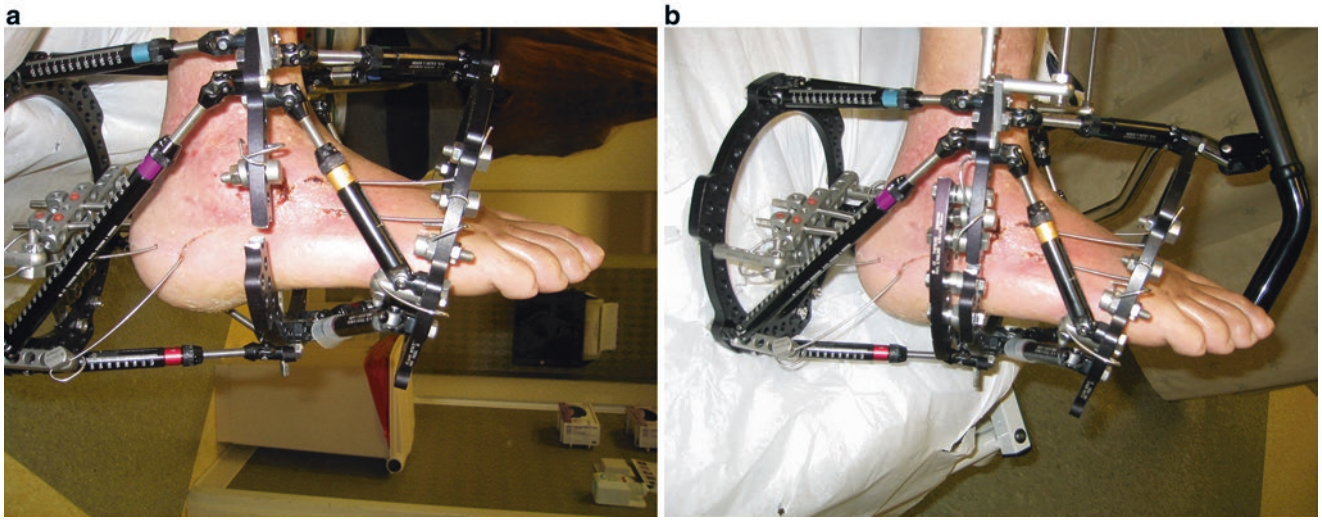

Fig. 30.7 Broken external fixation ring in a neuropathic patient (**a**) repaired by plating with additional ring (**b**) (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

even greater than six months. Patients must be well educated prior to initiating treatment in regards to the possibility of returning to the operating room for fixator adjustments and modifications during the course of treatment (Fig. 30.7). The foot and ankle surgeon must ensure that the patient is psychologically able to tolerate the external fixator. The patient's home environment must also be conducive to treatment.

Patients who have external fixation of the foot and ankle are in need of increased amount of follow-up with their surgeon. These patients often have very complex pathology and close surveillance, weekly or biweekly, is important to prevent complications from occurring. If these adverse events do occur, it is vital to ensure that proper care and intervention is rendered. The surgeon must have a capable support staff to care for these patients and their needs. Dressing changes, frame checks, component changes, all can take a substantial amount of time. Having a well-educated staff is important for handling these difficult cases.

Patient and family education is of vital importance when embarking on treatment with external fixation. We regularly have training sessions with patients prior to their surgical reconstruction to familiarize them with the equipment and the aftercare necessary to have a successful outcome. We also supply the patient with a manual of external fixation, which provides them a variety of information. The ability of the patient to tolerate the length of treatment often needed to undergo such intervention is crucial. The ability of family members to be present at home with the patient for support and assistance is also important postoperatively. Setting realistic goals and expectations with patients and their families prior to intervention is essential. Having a nurse or assistant with experience in the use of external fixation acting as a "point person" can assist the surgeon in handling phone calls and messages regarding the status of patients after hospital discharge. Although it is difficult to answer many questions without seeing the patient, some care and reassurance can be offered.

Building a Stable Frame

Circular External Fixation

Creating a stable external fixation construct is important in reducing the amount of complications. It is vital to understand the biomechanics of external fixation, both monolateral and circular [10]. Circular fixators are made of ring blocks, which consist of two rings and at least four points of fixation to a bone segment. Rings are connected with at least three threaded connecting rods. The stability of the ring block will increase with increasing the number of rings, decreasing the distance between the rings, controlling the near and far segments of the bone segments, increasing the number of connections between each ring, and increasing the number of points of fixation to the bone segment. Smaller diameter rings are more stable than larger diameter rings when of the same thickness. The smallest ring that accommodates a patient's extremity should be utilized, allowing for approximately 2 cm of clearance between the skin and the inner surface of the ring. The distance between rings also influences frame stability. Increasing the distance between rings allows for motion between them. Utilizing a "dummy" ring (a ring with no osseous fixation) will shorten the length of the connecting rods and increase the stability. The use of thicker telescoping rods will also help impart stability as

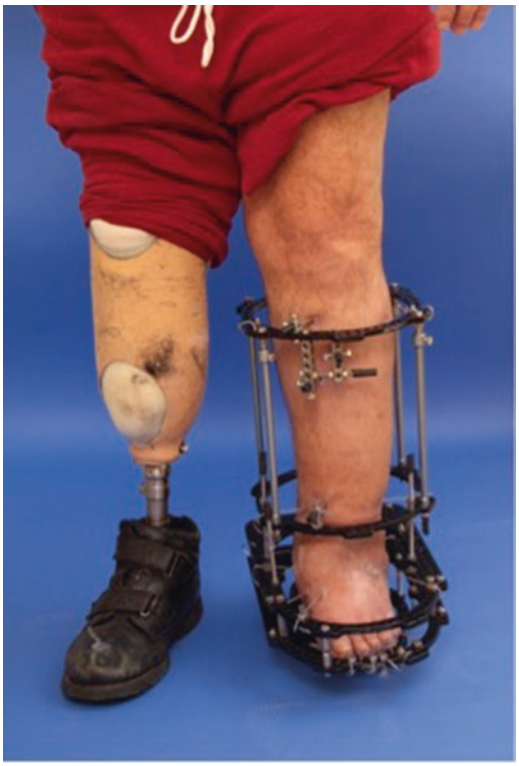

Fig. 30.8 Stable external fixation: a large tibial block allows for avoidance of placing fixation in the isthmus of the tibia, which is a high-risk zone for fracture. This strategy allows for increased stability of the tibia and disperses the stress of the fixation over a larger area. Note a foot ring block is used for increased stability (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

they have superior bending strength when compared to threaded connecting rods (Fig. 30.8).

The type of fixation to the bone segment also affects frame stability. Each ring block should have a minimum of four points of fixation (each ring a minimum of two points). The use of thin wires versus half-pin fixation is per surgeon discretion, anatomic considerations, and biomechanical principles. Increasing the number of wires, placing wires above and below a ring, and inserting wires in difference planes (oblique wires) all enhance stability. Knowledge of anatomic safe zones is of vital importance when placing both half-pins and thin wires so as not to entrap neurovascular and musculotendinous structures. Proper tensioning of thin wires enhances stability. Wires in the distal tibia are tensioned to 130 kg, in the calcaneus 100 kg, and in the midfoot/forefoot region 90 kg. Careful attention should be paid to the ring during tensioning so as not to cause deflection (bending) of the ring. When utilizing a foot plate, make sure to close the foot plate before tensioning the foot wires so as not to distort the ring.

The use of half-pin fixation (4, 5, or 6 mm diameter) is common in limb lengthening and deformity correction. Their use in neuropathic patients should be done with caution as this may increase the risk for tibial stress fractures [9]. Increasing the diameter of the pins increases the rigidity of fixation. Half-pins should be predrilled with a sharp drill bit and inserted bicortical by hand. Unicortical half-pins increase the risk of fracture and should be avoided. We commonly use hydroxyapatite (HA)-coated half-pins, which increases the pull out strength of the fixation. The diameter of the half-pin should be no more than one-third the width of the bone diameter to minimize the risk of fracture. By increasing the half-pin diameter by 1 mm, the strength increases exponentially.

A stable circular external fixation construct will allow patients the ability to bear weight early. This will allow for axial loading of the fracture or osteotomy site and stimulate bone healing. It should be kept in mind that when weight bearing after midfoot/forefoot procedures, axial loading can cause cantilever loading. Patients with neuropathy should be educated on limiting their ambulation due to their diminished proprioception. Excessive weight bearing in neuropathic patients can lead to pin/wire loosening, pin tract infections, and broken fixation components.

Monolateral External Fixation

Constructing a stable monolateral (unilateral) external fixation device follow similar concepts to that of a circular external fixator. Monolataral devices can be divided into monobody designs and pin-to-bar fixators. The primary difference is the use of all half-pin fixation. These devices are commonly utilized for femoral, tibial, and metatarsal deformity correction. Stability of these devices increases by using larger diameter pins, decreasing the distance between the frame and the bone, controlling both the far and near ends of each bone segment, increasing the number of connecting rods, placing pins obliquely to one another, and adding an additional monolateral fixator for multiplanar stability. The primary downside to the use of monolateral external fixation is that the far cortex is more difficult to gain compression or distraction in comparison to the near cortex. Monolateral external fixators demonstrate cantilever bending when axial load is applied. Monolateral fixators are commonly used in our practice for gradual distraction of metatarsal deformities (i.e., brachymetatarsia). Protected weight bearing in a wooden bottom surgical shoe is important to prevent any acquired deformity of the regenerate bone.

Frame removal

Dynamization is an important concept to consider prior to frame removal. Dynamization allows for the stress of weight bearing to be gradually transferred from the external fixator to the bone. This is particularly important when regenerate bone is healing from procedures such as lengthening or gradual deformity correction. Dynamization has been shown to accelerate bone healing [11]. Once osteotomy or arthrodesis healing has been achieved, the frame is dynamized by reducing the stiffness through removal or detachment of fixation pins/wires from each ring. This allows the osteotomy or arthrodesis site to "mature" and accept full weight once the frame is entirely removed. During the dynamization process, the surgeon must be aware that delayed union, refracture, or development of secondary deformity may occur. Only weeks after dynamization does the bone completely heal.

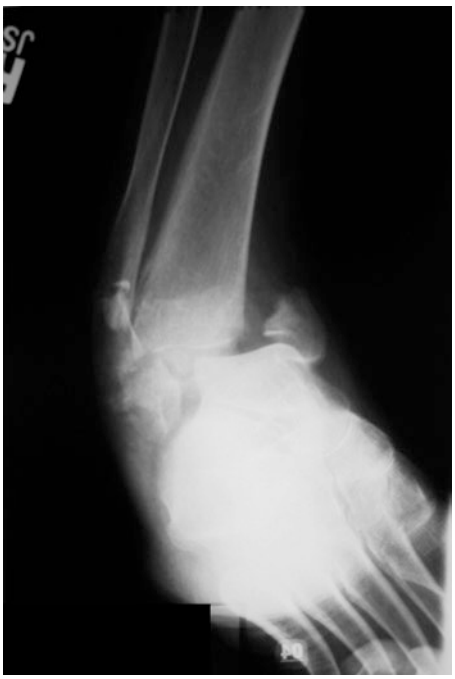

Fig. 30.9 Preoperative radiograph of trimalleolar ankle fracture dislocation (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Clinical Cases with Use of External Fixation

Case Example #1: Complex Ankle Arthrodesis

Sixty-two-year-old female referred after a failed ORIF of a right trimalleolar ankle fracture with subsequent ankle subluxation and development of ankle arthritis (Figs. 30.9 and 30.10). She had been diagnosed with idiopathic neuropathy. Circular external fixation was used because of concern for Charcot neuroarthropathy of the ankle and severe osteopenia. She underwent successful fusion of the ankle joint with subtalar joint distraction (Figs. 30.11 and 30.12). A stable fusion was obtained with a plantigrade foot (Fig. 30.13). She was able to ambulate brace-free without an assistive device following the procedure.

Case Example #2: Equinus Deformity Correction

Forty-year-old male presented with severe fixed equinovarus deformity and post-polio syndrome without prior surgery (Figs. 30.14 and 30.15). Circular external fixation

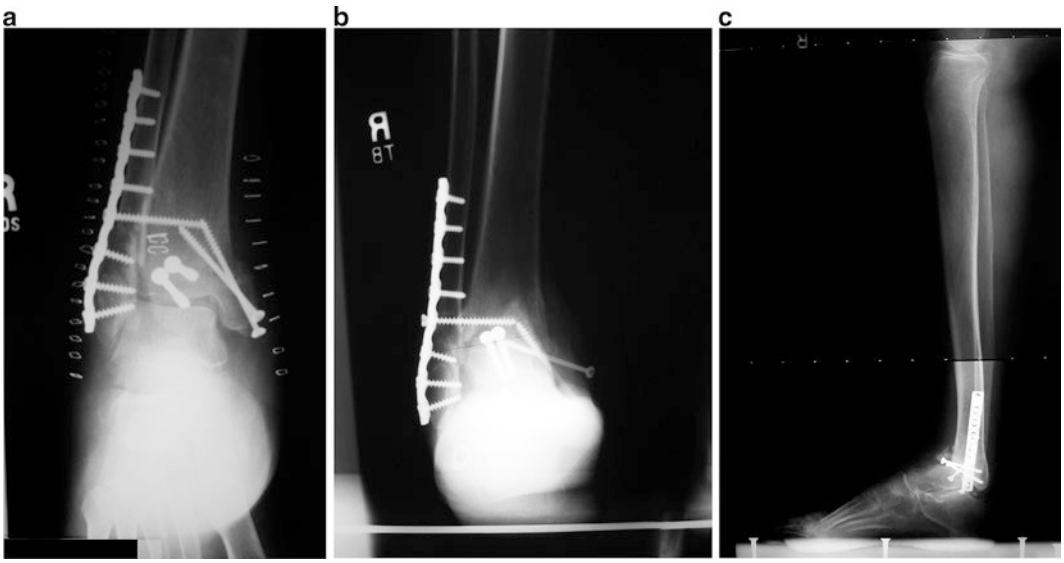

Fig. 30.10 Open reduction internal fixation of trimalleolar ankle fracture (**a**) and subsequent ankle degeneration and subluxation (**b**, **c**) (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

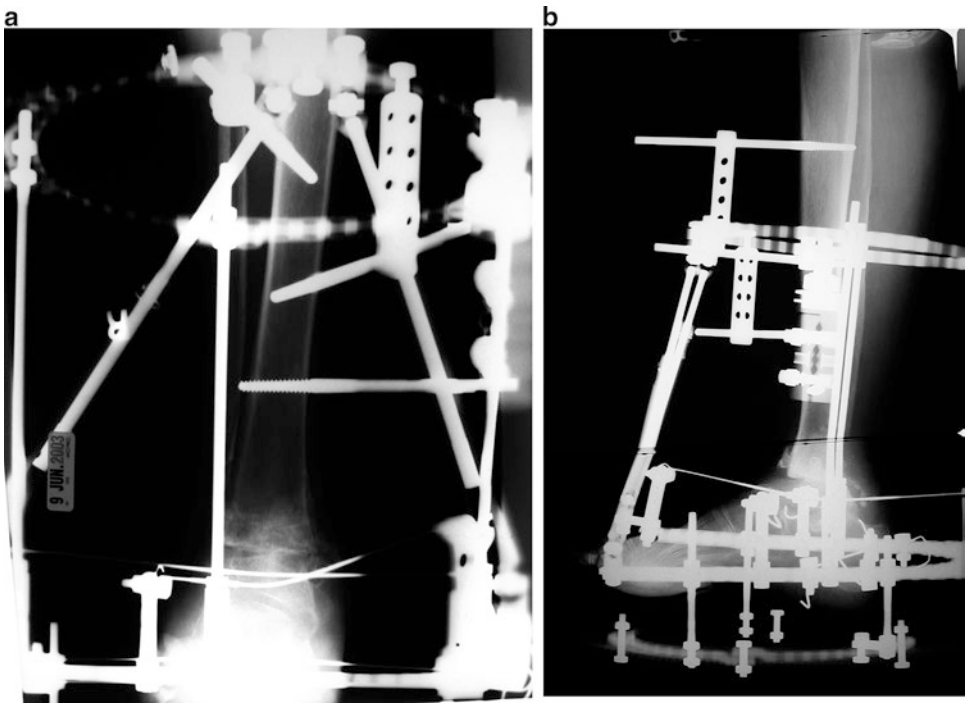

Fig. 30.11 Circular external fixation utilized for ankle arthrodesis and subtalar joint distraction (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

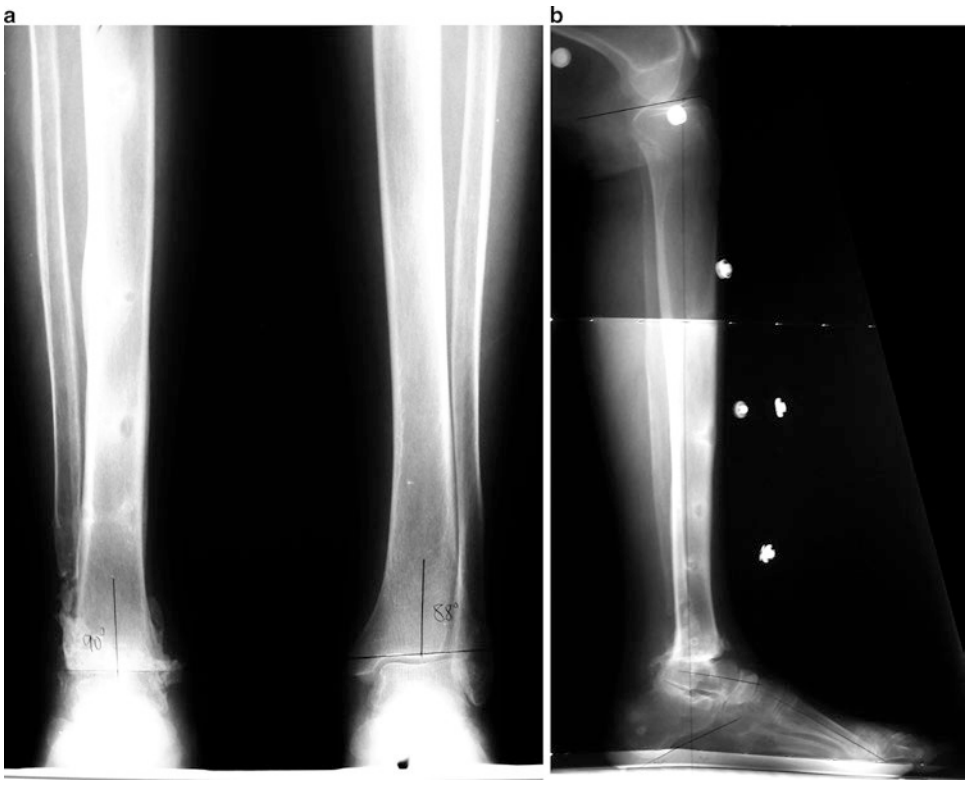

Fig. 30.12 Postoperative radiographic evaluation showing successful fusion of the subtalar joint and maintenance of the subtalar joint (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

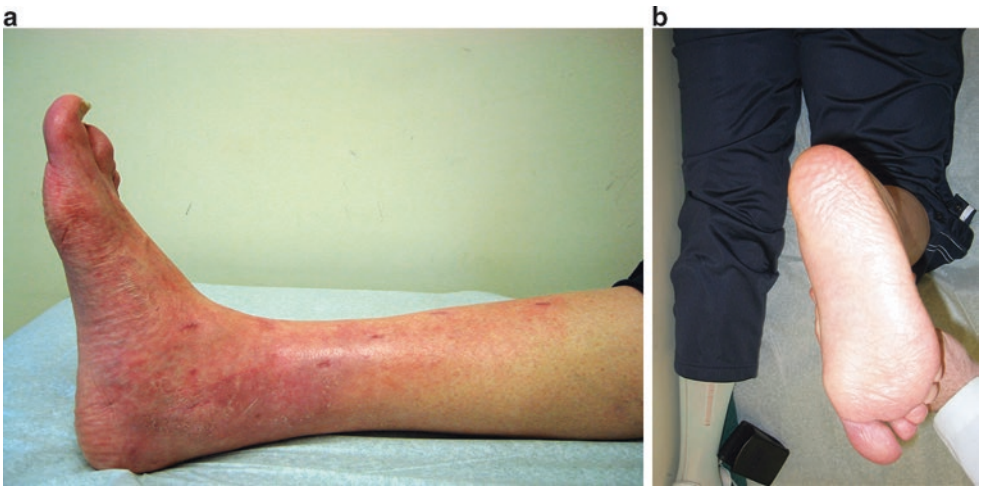

Fig. 30.13 Clinical photographs postoperatively showing a properly aligned ankle arthrodesis (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

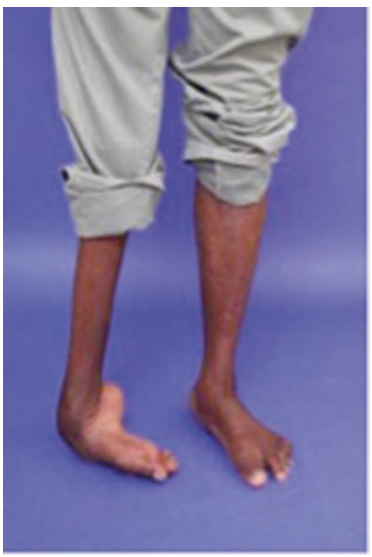

Fig. 30.14 Preoperative clinical presentation of severe equinovarus deformity (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

was used for gradual soft tissue correction of the foot and ankle to a plantigrade position. The first stage included correction of the equinus contracture, followed by modification of the external fixator for the second stage correction of varus foot deformity (Figs. 30.16 and 30.17). The patient did also have a knee flexion contracture, which was treated with casting, bracing, and physical therapy. He has had no recurrence of the deformity and is walking with a plantigrade foot position 2 years following his surgery (Fig. 30.18).

Case Example #3: Charcot Midfoot Reconstruction

Forty-three-year-old male was referred with right midfoot Charcot deformity and chronic non-healing lateral column wound (Fig. 30.19). His condition was complicated by a history of kidney and pancreas transplant requiring immunosuppressant therapy. He had been treated with total contact cast immobilization without wound improvement. He underwent midfoot Gigli saw osteotomy (talar neck and calcaneal neck osteotomy) and gradual deformity correction with multiplanar external fixation (Fig. 30.20). The foot position was gradually corrected out of abduction and varus and then compressed for realignment arthrodesis of the midfoot osteotomy (Fig. 30.21). Due to the external fixation construct (butt frame) used to correct this patients deformity, he was unable to bear weight during his course of treatment. Only minimal incisions were made and the patient healed without any bone or soft tissue complications. He now walks with diabetic shoe gear and he is brace- and wound-free (Fig. 30.22).

Case Example #4: Gradual Distraction for Brachymetatarsia Correction

Thirty-two-year-old male presented with bilateral brachymetatarsia of the fourth metatarsal and hypoplastic fourth toe (Figs. 30.23 and 30.24). He underwent gradual distraction for correction of the bilateral brachymetatarsia. The external fixator construct included bridging to the fourth toe to reposition the fourth MTP joint and prevent joint subluxation/dislocation during the lengthening phase (Fig. 30.25). He underwent 33 days of lengthening to create a normal metatarsal parabola. Following consolidation of the regenerate bone, his bilateral fixators were removed in clinic approximately 4 months postoperatively (Fig. 30.26). Throughout his entire treatment, he was weight bearing as tolerated in wooden bottom surgical shoes.

Conclusion

External fixation is often utilized for high-risk, revisional, and complex cases because of its modularity, dynamic nature, and ability for patients to maintain weight bearing throughout the course of treatment. This inherently

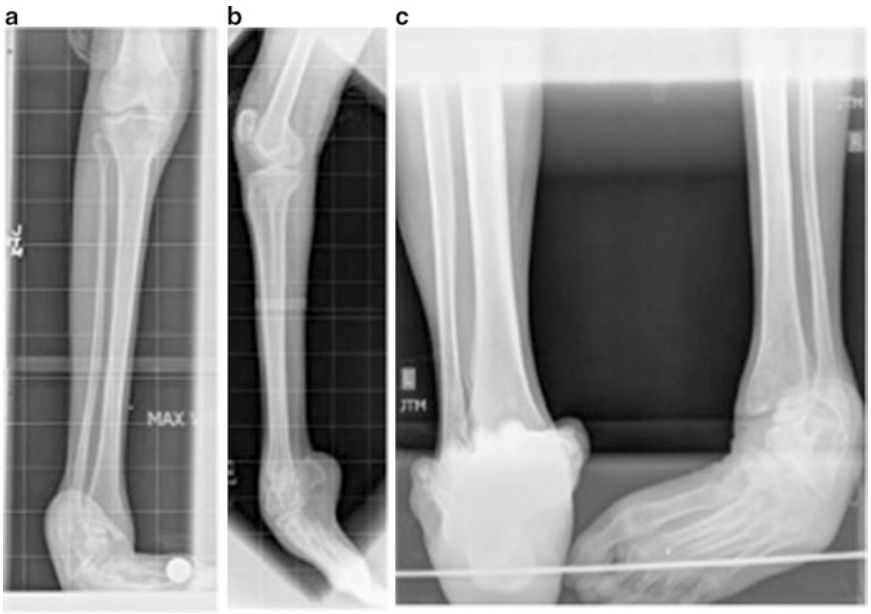

Fig. 30.15 Preoperative radiographic presentation of severe equinovarus deformity (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

Fig. 30.16 Clinical pictures during treatment of severe equinovarus deformity with external fixation. Deformity correction was accomplished through gradual distraction with a semi-constrained construct. This two-stage approach included first correcting the equinus deformity of the ankle, followed by correction of the varus deformity of the foot (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

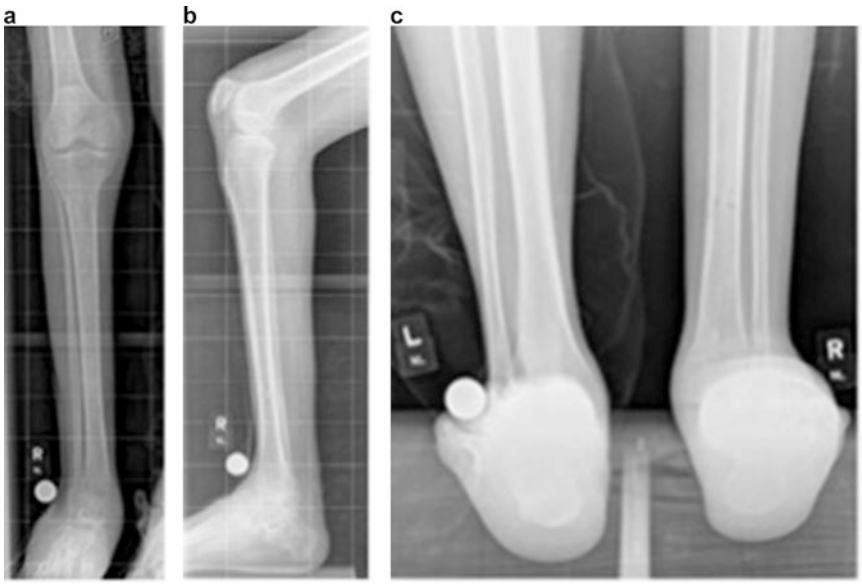

Fig. 30.17 Postoperative radiographic presentation of a plantigrade foot following gradual correction of severe equniovarus deformity (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

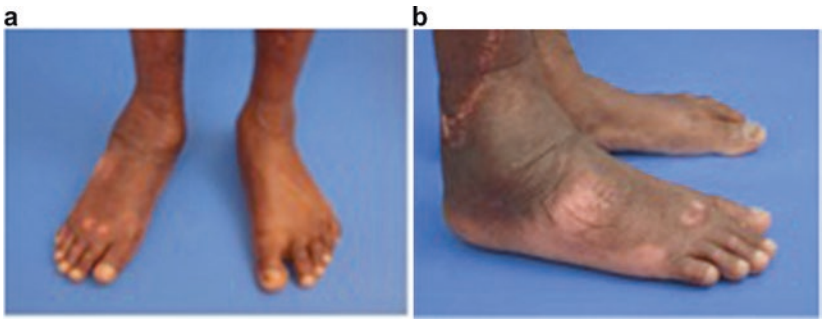

Fig. 30.18 Postoperative clinical presentation of a plantigrade foot following gradual correction of severe equniovarus deformity with circular external fixation (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

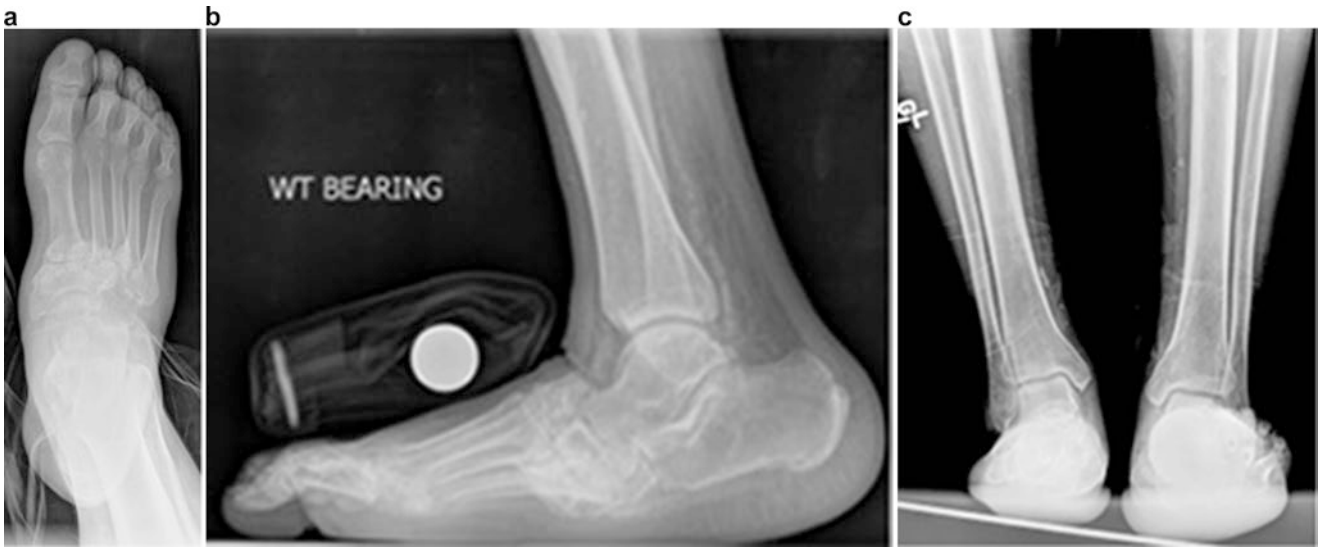

Fig. 30.19 Preoperative radiographic presentation of Charcot neuroarthropathy of the midfoot resulting in a rocker-bottom deformity and non-healing ulceration (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

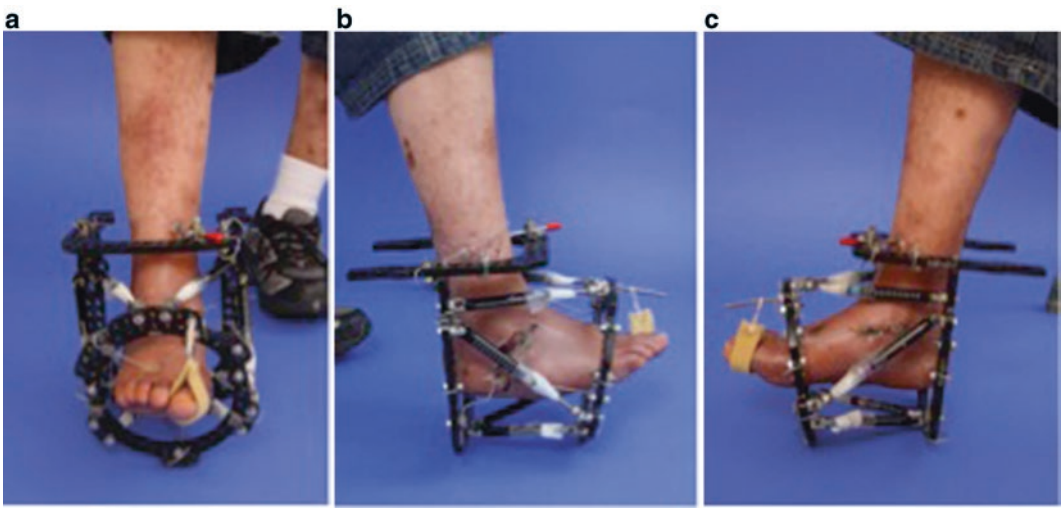

Fig. 30.20 Clinical presentation during treatment with six-axis correction construct used to obtain and maintain correction of the midfoot deformity following minimally invasive osteotomy (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

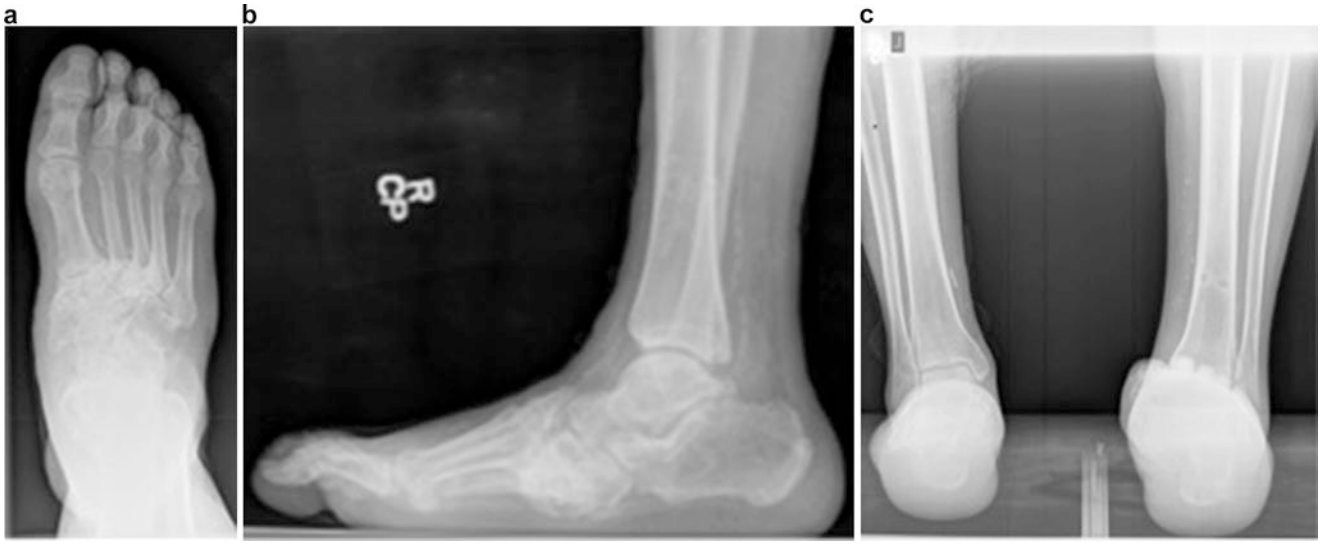

Fig. 30.21 Postoperative radiographic presentation following correction and stabilization of midfoot deformity (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

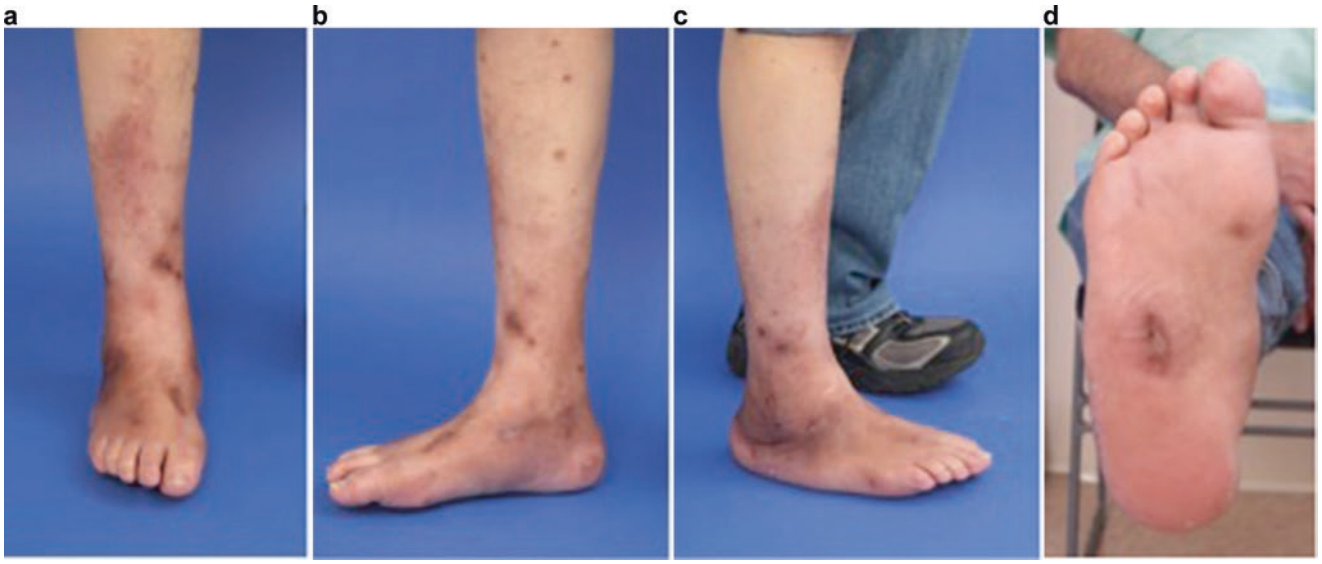

Fig. 30.22 Clinical presentation following correction of midfoot deformity shows a plantigrade foot and healed plantar ulceration (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

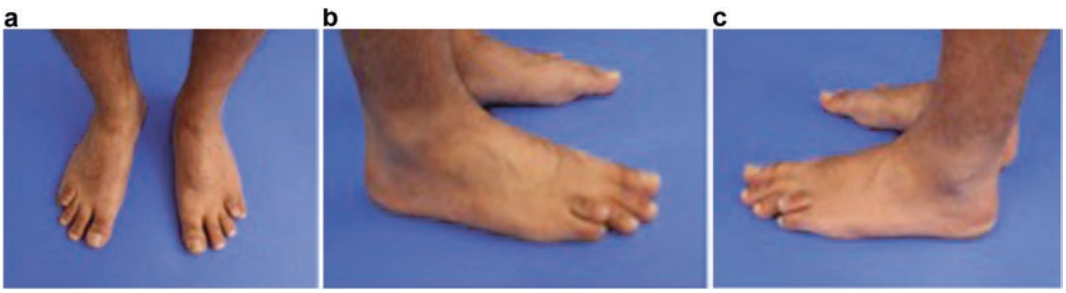

Fig. 30.23 Preoperative clinical presentation of bilateral fourth brachymetatarsia (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

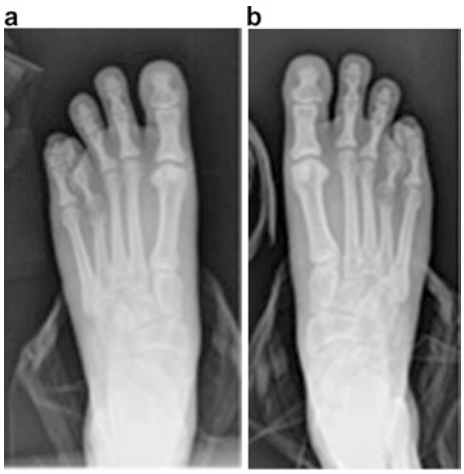

Fig. 30.24 Preoperative radiographic presentation of bilateral fourth brachymetatarsia and hypoplastic fourth digit. Note the subluxation of the fourth metatarsophalangeal joint (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

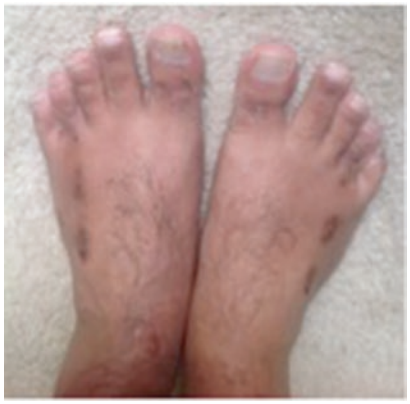

Fig. 30.26 Clinical presentation following gradual distraction for correction of brachymetatarsia (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

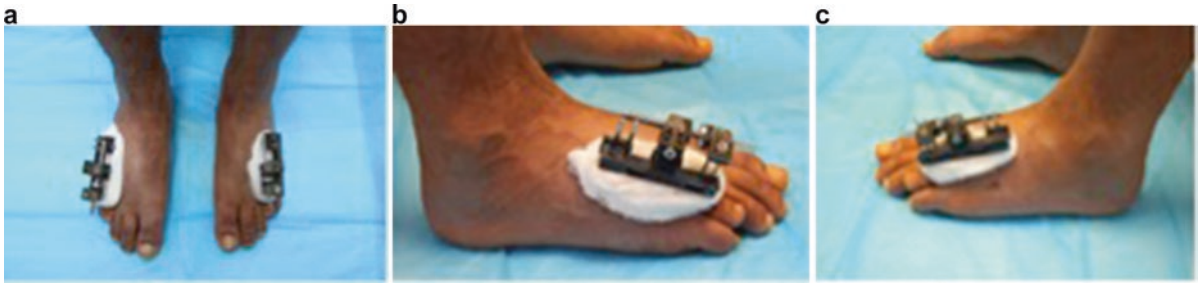

Fig. 30.25 Clinical presentation during gradual distraction for correction of fourth brachymetatarsia. Note the extension of the external fixator to the fourth digit to reduce and protect the metatarsophalangeal joint during the distraction process (Reprinted with permission from the Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore)

increases the likelihood of problems, obstacles, and complications. Not all adverse events are complications. Problems and obstacles are often encountered with external fixation without interfering with the goals of treatment. Patient education is of critical importance when preparing patients to undergo treatment with external fixation. Experience, training, and a thorough understanding of problems and obstacles complications decrease the risk of complications.

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