

# Diabetic Neuropathic Forefoot, Midfoot, and Hindfoot Osseous Trauma and Dislocations

## INTRODUCTION

According to the American Diabetes Association (ADA) in 2005, 1.5 million new cases of diabetes mellitus were diagnosed. The ADA also reported that the incidence of diabetes mellitus in the United States was prevalent among 20.8 million people, which accounted for 7% of the United States population. This disease has reached epidemic proportions in the United States as well as around the globe. The World Health Organization estimates that currently, there are 171 million people with diabetes mellitus, and it is projected that by the year 2030 the prevalence will escalate to 366 million people (1).

Peripheral neuropathy is a serious and significant complication of diabetes mellitus that affects >50% of patients with diabetes. The highest rates of peripheral neuropathy are among people who have had diabetes for at least 25 years, are >40 years of age, and have had poorly controlled glycemic levels as well as other cardiovascular risks, such as obesity and hypertension (1). In addition, those patients with diabetes mellitus and neuropathy are reported to have a reduced bone mass and severe osteopenia (2).

Peripheral neuropathy and peripheral vascular disease play a significant role in the development of surgical complications and can create significant limb-threatening scenarios if left untreated or misdiagnosed (3). Peripheral neuropathy alone is considered an indicator for unfavorable prognosis for lower extremity trauma. Patients with peripheral neuropathy are difficult to manage because of their loss of sensation and failure to sense infection secondary to trauma and/or soft tissue complications.

The neuropathic patient who experiences lower extremity fractures and/or dislocations presents a great challenge to the treating physician. Typically, trauma surgeons use external fixation to temporarily stabilize fractures until the soft tissue envelopes are ready for surgery (4). Open reduction internal fixation (ORIF) is then executed following the decrease in soft tissue swelling and the return of skin lines in the nonvascular compromised patient (5). This chapter discusses the use of external and/or internal fixation as a primary and definitive treatment for this difficult-to-treat patient population.

## INDICATIONS/CONTRAINDICATIONS

External fixation is much less invasive to the soft tissue envelope when it is performed percutaneously. A methodical preoperative assessment of potential operative candidates will support the surgeon with suitable selection criteria. Supporting documentation reveals that medically compromised patients, such as those with diabetes mellitus, rheumatoid arthritis, extensive smoking history, vascular impairment, and morbid obesity do not fare as well with standard open surgery and are more appropriate type of patients for external fixation. One must also consider and evaluate anesthesia risks with external fixation. Two considerations need to be understood: External fixation typically requires a significantly longer operative time than typical AO techniques, and in most scenarios a second anesthesia is needed on removal of the external fixator.

Appropriate candidates for the use of external fixation in reconstructive foot and ankle surgery include and are not limited to patients who have experienced trauma (high-energy open or closed fractures resulting in significant soft tissue injury), need for temporary fixation or staged procedures, bilateral lower extremity trauma, patients with impaired upper extremities that will not allow their upper body to be supported with crutches or other walking devices and direct visualization to flaps and soft tissue envelope.

Options for open and/or closed treatment exist for the neuropathic trauma patient. The respect of the soft tissue envelope is vital while providing stable rigid fixation. Characteristically, this patient population requires extensive detail to the soft tissues. Surgical wounds related to osseous and soft tissue injuries in patients with neuropathy often heal unsuccessfully. Preoperative evaluation of these cases includes performing a history and physical with a thorough lower extremity evaluation. This evaluation should include a detailed physical assessment specifically evaluating skin integrity and quality. In the acute traumatic patient, reduction of bony displacement is mandatory to eliminate tension from the skin to minimize the danger of skin necrosis. A sensory evaluation is needed preoperatively to determine if the patient is neuropathic. Differentiating between

acute and chronic trauma from Charcot neuroarthropathy is necessary. Traditionally, temporary splinting was required to prevent gross displacement until the time of surgery, which could sometimes place the soft tissues in jeopardy. If it can be determined that the patient is neuropathic upon completion of this preoperative evaluation, external fixation via smooth wire fixation may be considered as the definitive treatment option.

In addition to clinical evaluation, preoperative radiographic imaging typically warrants three views of the involved foot, ankle, lower extremity, and/or opposite side. More complex imaging may be necessary based on the physical exam. Magnetic resonance imaging (MRI) may be necessary for an evaluation associated with potential soft tissue damage and a computed tomography (CT) or 3D CT may be needed for a more detailed osseous assessment. If the radiographic testing demonstrates significant osseous displacement in this patient population, then external fixation is a viable option in treating neuropathic patients.

In treating neuropathic patients with significant trauma and/or dislocations, techniques other than external fixation may result in hazardous scenarios. The importance of limb salvage in both the idiopathic neuropathic and diabetic neuropathic population is a perfect example of why surgical reconstruction and early ambulation are needed. One study reported that 40% to 45% of all nontraumatic amputations in the United States result from diabetes (6). Once a diabetic patient loses a limb, the contralateral limb is placed at high risk. A second amputation occurred in 55% of these patients within 5 years (6). Other studies show that 30% of the patients die in the first 3 postamputation years, and 60% die within the first 5 years (7). These findings prove that amputation is not only debilitating to the patient's quality of life, but also life-threatening in this patient population.

In contrast, absolute contraindications for definitive primary surgical reduction/treatment consist of scenarios in which patients present with active lower extremity infections, severe ischemia, or very poor glycemic control. Relative contraindications for definitive surgical reduction treatment consist of conditions in which patients are nonambulatory, noncompliant, and/or present with a very poor nutritional status, severe osteopenia, peripheral vascular disease, and multiple comorbidities, such as morbid obesity as well as renal and heart disease.

Considering the increasing number of patients with diabetes mellitus and the aging population in the United States and around the world, it is essential that foot and ankle surgeons are able to identify these scenarios and treat these patients more suitably. The importance of limb preservation is paramount, and external fixation is an essential means of minimizing patient complications in the diabetic neuropathic population.

### **SURGICAL TECHNIQUE FOR THE NEUROPATHIC FOREFOOT/MIDFOOT OSSEOUS TRAUMA AND DISLOCATIONS**

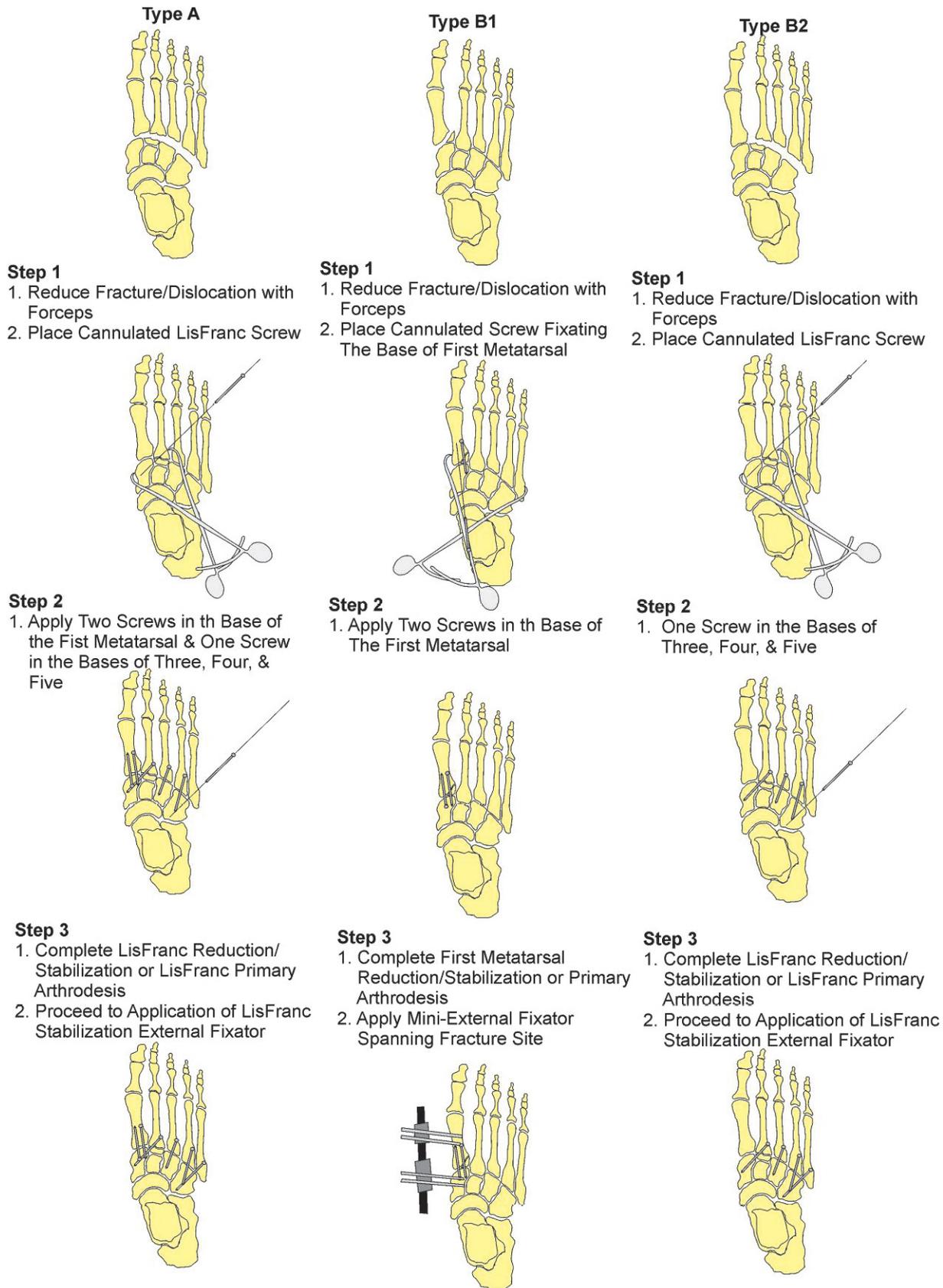
Surgical treatment of the neuropathic forefoot/midfoot osseous trauma and dislocations may be addressed with a traditional surgical approach with some additional steps needed to ensure healing and decrease complications. The initial clinical presentation is a valuable predictor of what additional surgical steps might be required. Radiographic examination of the pathologic foot is absolutely necessary any time a neuropathic patient describes a questionable event or related symptoms.

Subtle dislocations should be further examined by radiographic comparison of the contralateral foot. A CT scan may also be obtained to confirm a diagnosis and determine the severity of pathology. Undiagnosed and improperly treated forefoot and/or midfoot osseous trauma and dislocations can rapidly progress into a Charcot joint collapse. The severity of peripheral neuropathy indicates that the patient will most likely weight-bear prematurely and has an extremely high risk of developing an acute Charcot event.

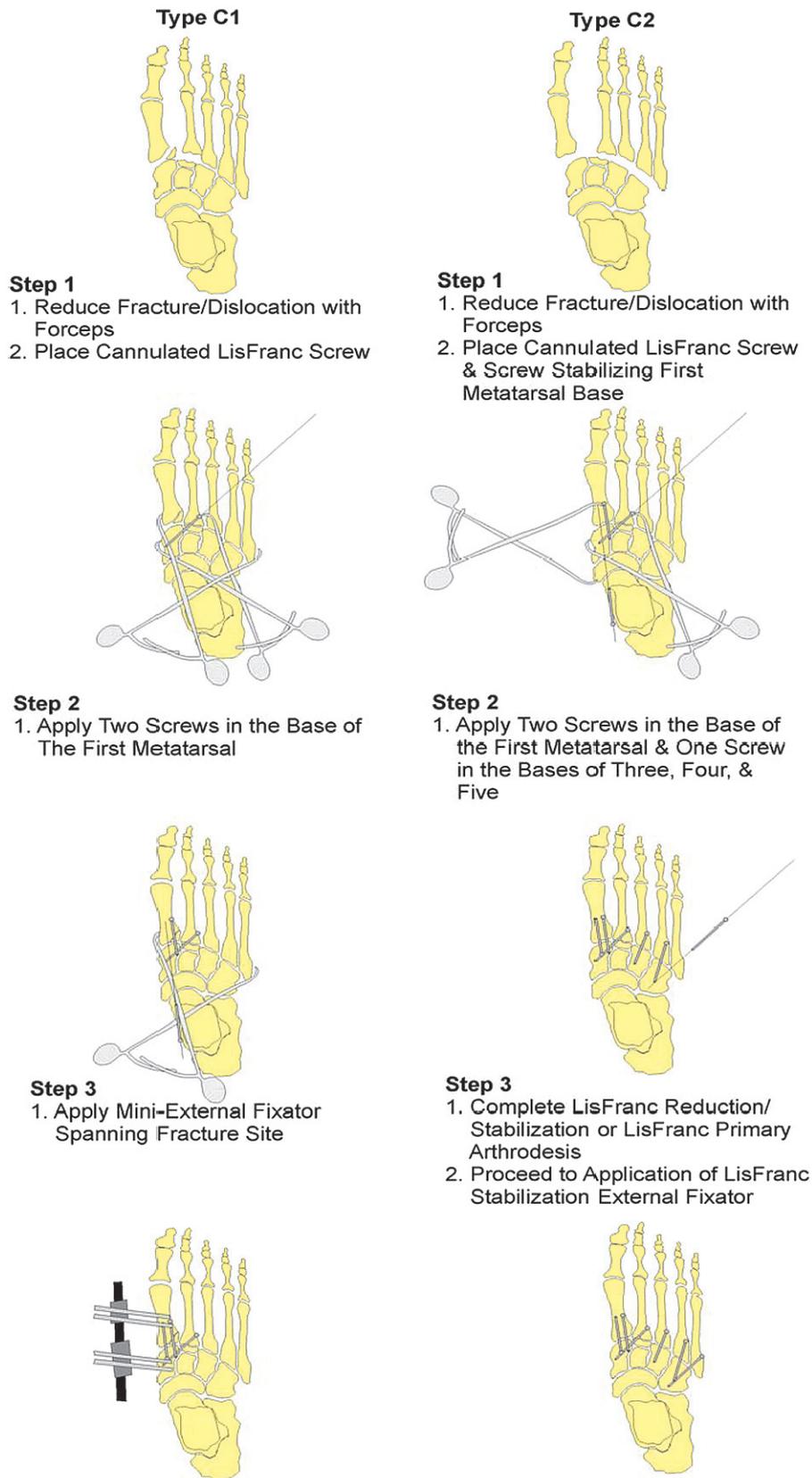
It is the authors' opinion that these patients will better benefit with a primary arthrodesis of the affected collapsed joint(s) with multiple screws, multi-ring external fixation with a foot plate for additional stabilization and joint compression, and a possible percutaneous tendo-Achilles lengthening. A primary arthrodesis may not be necessary if the presentation of the trauma is more traditional to a patient in the early stages of diabetic neuropathy and who is unable to weight-bear secondary to discomfort. It is also the authors' opinion that the vast majority of diabetic neuropathic patients who sustain forefoot/midfoot osseous trauma and dislocations will benefit from external fixation. The deciding factor of whether a circular multi-ring or monolateral/hybrid external fixation system is used depends on the severity of the initial trauma presentation.

A wide variety of forefoot/midfoot trauma exists. Forefoot trauma may be classified and described by the Hardcastle tarsometatarsal joint injury classification (8). If the patient is able to have surgery performed within 3 to 5 days from the traumatic event, the likelihood of a percutaneous reduction and stabilization is acceptable. Beyond this time frame, it is likely that an open approach will be needed using a two to three dorsal incisional approach. The keystone of the metatarsal bases must be restored to anatomic alignment. Using bone reduction forceps, the fractured/dislocated metatarsals may be reduced and temporarily stabilized. The Lisfranc ligament must be recreated stabilizing the keystone by a 4-mm cancellous screw. Depending on what other tarsometatarsal fractures/dislocations have occurred, it will determine whether additional screw fixation will be needed. It is the authors' preferred technique for lesser metatarsal bases to be fixated with one 4-mm cancellous screw in each metatarsal that was dislocated. The first metatarsal should be fixated with two 4-mm cancellous screws. After internal fixation has reduced and stabilized the traumatic pathology, a decision on which external fixation modality arises. Pathology described as Hardcastle B1 and C1 involve the medial column and second metatarsal only. Therefore, a mini-external fixator is the preferred choice. However, pathology described as Hardcastle A, B2, C2 involve multiple metatarsals (Figs. 25.1 and 25.2). These types of fracture dislocations are much more traumatic and unstable. A tarsometatarsal multi-ring external fixator consisting of a proximal ring, ankle ring, and a foot plate is then recommended.

The tarsometatarsal external fixator is applied in the following fashion. The chosen configuration is similar to the ankle joint stabilization frame consisting of two full rings and a foot plate connected by four threaded rods. The distance from the foot plate to the ankle joint should place the ankle ring 2 to 4 cm above the ankle joint. The proximal ring distance from the ankle joint should be 150 mm from the ankle ring. The prebuilt external fixation is placed over the foot and lower extremity. The foot plate is placed to allow plantar projection of the heel. A transosseous calcaneal wire is



**Figure 25.1** Neuropathic technique for Hardcastle A, B1, and B2.



**Figure 25.2** Neuropathic technique for Hardcastle C1 and C2.

placed medial to lateral and tensioned to 70- to 90-kg force. Two converging transosseous tibial wires are placed on the proximal ring and ankle ring and tensioned to 110- to 130-kg force. Once the proximal fixation block is stabilized, a second converging calcaneal wire is placed. The next wire is the midfoot wire. This wire serves two purposes. It stabilizes the midfoot and serves as a stable block that allows the metatarsal wire rebound force for compression of the Lisfranc's joint. The midfoot wire is a transosseous wire placed from medial to lateral coursing from the proximal medial cuneiform and exiting at the cuboid. The olive must be abutting the cortex of the medial cuneiform. The midfoot wire is then tensioned to 70-kg force and secured to the foot plate. The metatarsal wire is next placed from lateral to medial serving two purposes. This wire stabilizes the forefoot and compresses the bases of the metatarsals against the cuneiforms and cuboid. The metatarsal wire is a transosseous wire placed from lateral to medial. This wire should course through the bases of at least three metatarsals with the olive abutting the lateral cortex of either the fourth or fifth metatarsal. After this wire is placed, make note of where the wire lies on the foot plate both medially and laterally. Secure the wire back toward the rearfoot by one to two foot plate holes. Loosely fixate the metatarsal wire in this position medially and laterally to the foot plate. A tensioner is then placed medially and laterally on the wire. Gently both tensioners are simultaneously tightened to about 20- to 30-kg force. The wire is then secured to the foot plate. The tarsometatarsal stabilization external fixator is now completed (Figs. 25.3 and 25.4).

Isolated midfoot and forefoot fracture/dislocations outside the Lisfranc's joint in diabetic neuropathic patients also benefit from traditional surgical approaches with the addition of reduction and stabilization using a mini-external fixator. The mini-external fixator has the ability to aid in reduction and stabilization of the fracture pathology throughout the postoperative course. Reduction techniques may be used in fracture pathology involving bones of the medial cuneiform, navicular, and cuboid. By inserting two 3.5-mm fixator pins proximal and distal to the fracture bone, the external fixator is then adjusted by lengthening the distance between the proximal and distal fixator pins. This mechanism creates a reduction force using ligamentotaxis. Once the fracture is reduced, it needs stabilization and compression by one to two 4.0-mm cannulated screws. When dealing with a fractured metatarsal, the insertion of a Kirschner wire for stabilization and realignment can be performed. However, when multiple metatarsals are fractured, a mini-external fixator is added to the K-wire fixation for further stability. A size ranging from 2.5- to 3.5-mm mini-external fixator pins are positioned with two pins distal to the fracture and two pins proximal to the fracture. Distally, one pin may be placed in the base of the proximal phalanx and a second pin placed in the head/neck area of the corresponding metatarsal. Proximally, two pins are placed in the base of the metatarsal (Fig. 25.5).

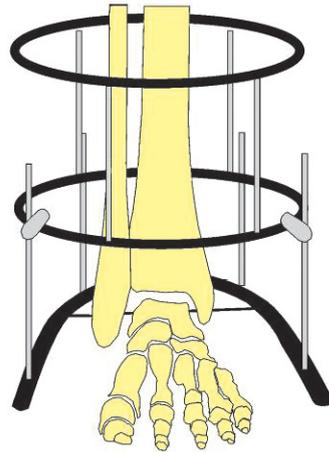
### **SURGICAL TECHNIQUE FOR THE NEUROPATHIC HINDFOOT OSSEOUS TRAUMA AND DISLOCATIONS**

It is the authors' opinion that diabetic patients with dense peripheral neuropathy and severely comminuted intra-articular

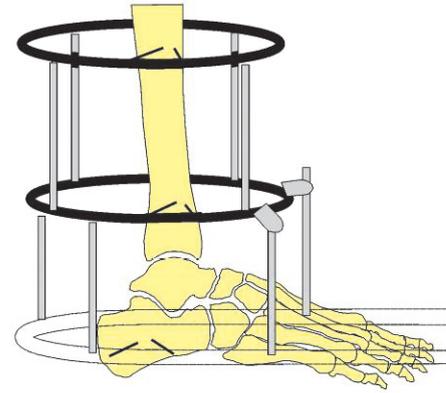
calcaneal fractures will better benefit with a primary arthrodesis of the subtalar joint with the use of multi-ring external fixation and a foot plate for additional stabilization and joint compression. If the presentation of the trauma is more traditional and a CT scan shows an extra-articular calcaneal fracture in a patient with early stages of diabetic neuropathy, then a primary arthrodesis may not be necessary. It is also the authors' opinion that the vast majority of diabetic neuropathic patients who sustain open or closed hindfoot osseous trauma and dislocations will benefit from external fixation. A wide variety of hindfoot trauma exists according to CT scan classifications. If the diabetic patient with dense peripheral neuropathy is able to have surgery performed within 3 to 5 days from the traumatic event, the likelihood of a percutaneous or mini-open reduction and stabilization with an external fixator is acceptable. Beyond this time frame, it is likely that an open approach will be needed for the calcaneal fracture repair or primary subtalar joint arthrodesis.

The surgical procedure of either the calcaneal fracture repair or primary subtalar joint arthrodesis begins by placing a large transfixing Steinmann pin through the calcaneus and simultaneous distraction of the subtalar and ankle joint. Fluoroscopic imaging is paramount at this point and an intraoperative decision of a percutaneous versus mini-open incisional approach is made. It is recommended that the distraction is allowed for at least 10 minutes before the surgical procedure or even perform the entire procedure under the desired distraction technique described in the preceding. For the primary subtalar joint arthrodesis, a 3- to 4-cm skin incision is made directly over the subtalar joint and blunt dissection is performed to the level of the lateral wall of the calcaneus. Care is then taken to avoid injury at the peroneal tendons and sural nerve. It is the authors' technique to reflect the lateral calcaneal wall and bluntly lift the subtalar joint into anatomic alignment. At that time, if the articular joint cartilage is severely damaged, the joint is resected with a sagittal saw or aggressive curettage technique. Corticocancellous allogenic bone grafting is also recommended for the primary arthrodesis. The subtalar joint can then be temporarily stabilized with a large Steinmann pin and the skin is closed with a 3-0 nylon suture. The tourniquet, which is highly recommended during the procedure, is then released before the external fixation application.

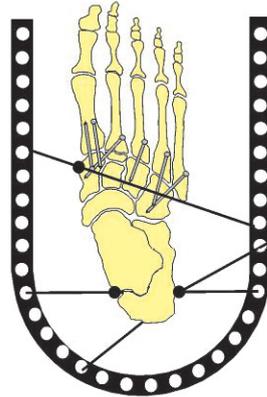
The hindfoot external fixator is applied in the following fashion. The chosen configuration is similar to the neuropathic forefoot stabilization frame consisting of two full rings and a foot plate connected by four threaded rods. The distance from the foot plate to the ankle joint should place the ankle ring 2 to 4 cm above the ankle joint. The proximal ring distance from the ankle joint should be 150 mm from the ankle ring. The prebuilt external fixation is placed over the foot and ankle. The foot plate is placed to allow plantar projection of the heel. Two transosseous calcaneal olive wires are placed from lateral to medial and tensioned from the medial side to 70- to 90-kg force. This allows fixation and stabilization of the lateral wall of the calcaneus. Two converging transosseous tibial wires are placed upon the proximal ring and ankle ring and tensioned to 110- to 130-kg force. Once the proximal fixation block is stabilized, a third converging calcaneal wire is placed from medial to lateral and tensioned to 70- to 90-kg force.



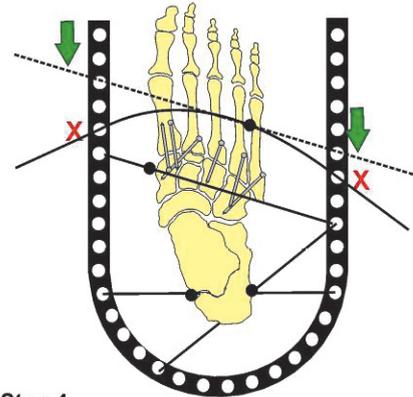
**Step 1**  
1. Apply LisFranc Stabilization Frame by Starting with Calcaneal Wire



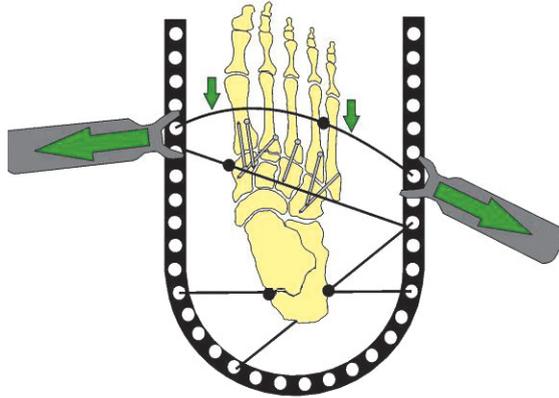
**Step 2**  
1. Stabilize Proximal Fixation Block with Two Converging Wires per Ring



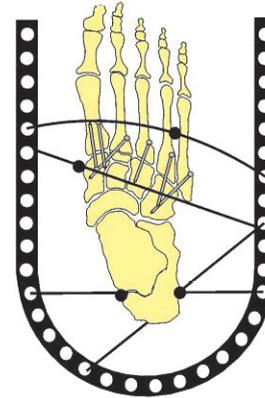
**Step 3**  
1. Place Second Converging Calcaneal Wire  
2. Place MidFoot Wire With Olive Medial Proximal to LisFranc's Joint & Tension



**Step 4**  
1. Place Metatarsal Wire Distal to LisFranc's Joint with the Olive Lateral  
2. Walk the Metatarsal Wire Posterior by One to Two Holes & Attach to Foot Plate

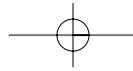


**Step 5**  
1. Place a Tensioner Medially & Laterally on the Metatarsal Wire  
2. Gently Tighten Both Tensioners to Approximately 20-30 Kg Force



**Step 6**  
1. Fixate Metarsal Wire to Foot Plate

**Figure 25.3** Neuropathic forefoot stabilization frame technique.



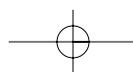
**Figure 25.4** Initial anteroposterior (AP) and lateral views (A,B) showing the subtle dislocation at the Lisfranc's joint, followed by a percutaneous ORIF and circular multi-ring external fixation (C,D). Final postoperative picture after external fixation removal (E).

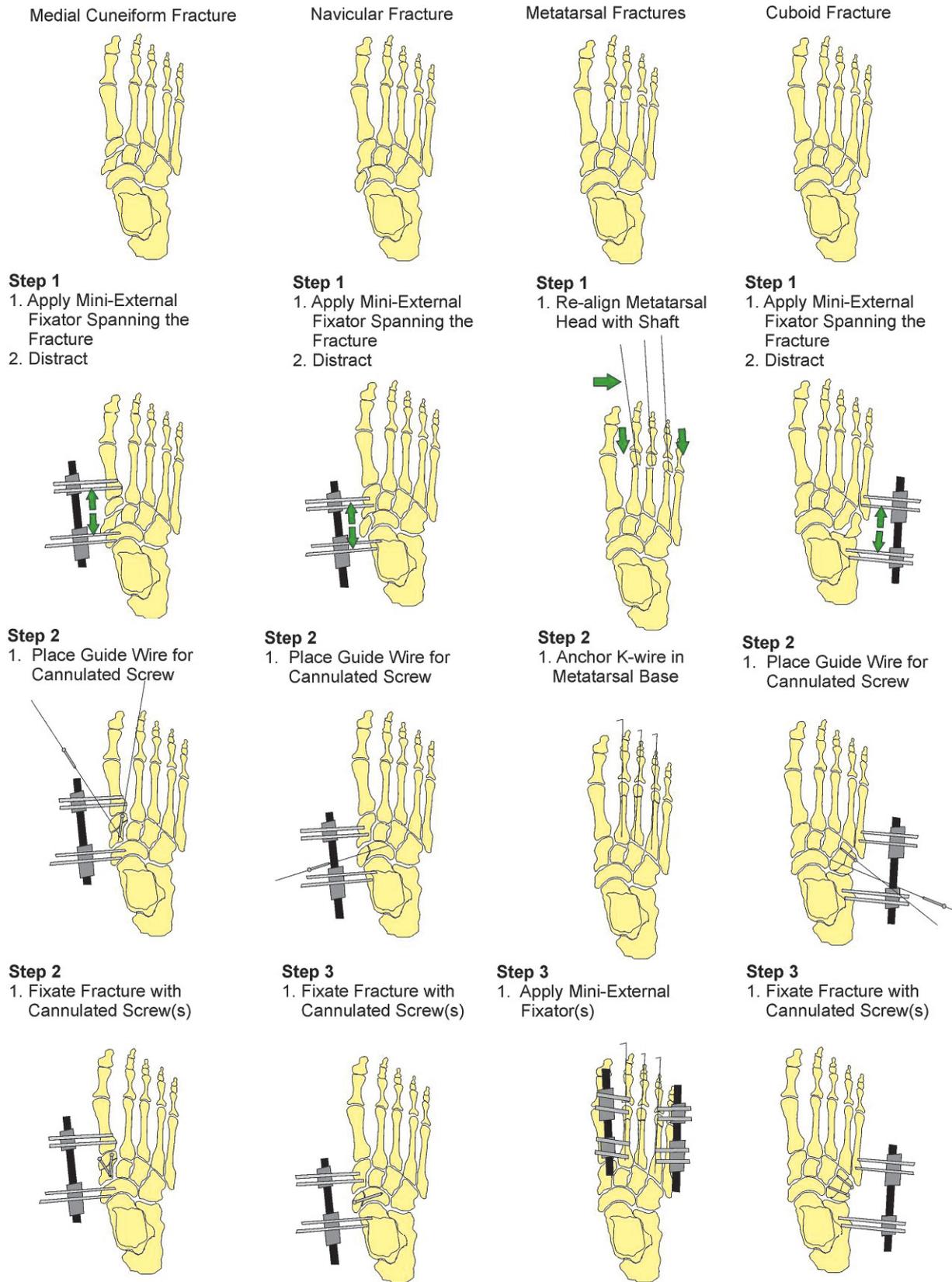
At that point, if an extra-articular calcaneal fracture is being repaired an extra midfoot wire is placed from medial to lateral and tensioned to 70- to 90-kg force. The midfoot wire is a transosseous wire coursing from the proximal medial cuneiform and exiting at the cuboid. The olive must be abutting the cortex of the medial cuneiform (Fig. 25.6A-J). If a primary arthrodesis is performed, a talar wire is then placed from medial to lateral side and manually tensioned at both sides to cause compression and stabilization across the subtalar joint. A second talar wire is also recommended for extra stability. The midfoot wire is then followed from medial to lateral coursing from the proximal me-

dial cuneiform and exiting at the cuboid. The olive must be abutting the cortex of the medial cuneiform and tensioned from lateral to medial side around 70- to 90-kg force (Fig. 25.7A-I).

It is paramount to complete all the parts of the external fixation by rechecking the levels of stability and rigidity, by counting the accessory parts, and by reviewing the intraoperative technique. For example, an extra bottom foot plate ring is added for the first 2 weeks for patient compliance and before dynamization and weight-bearing status. Final radiographic imaging is recommended at the end of the procedure.

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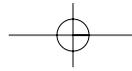




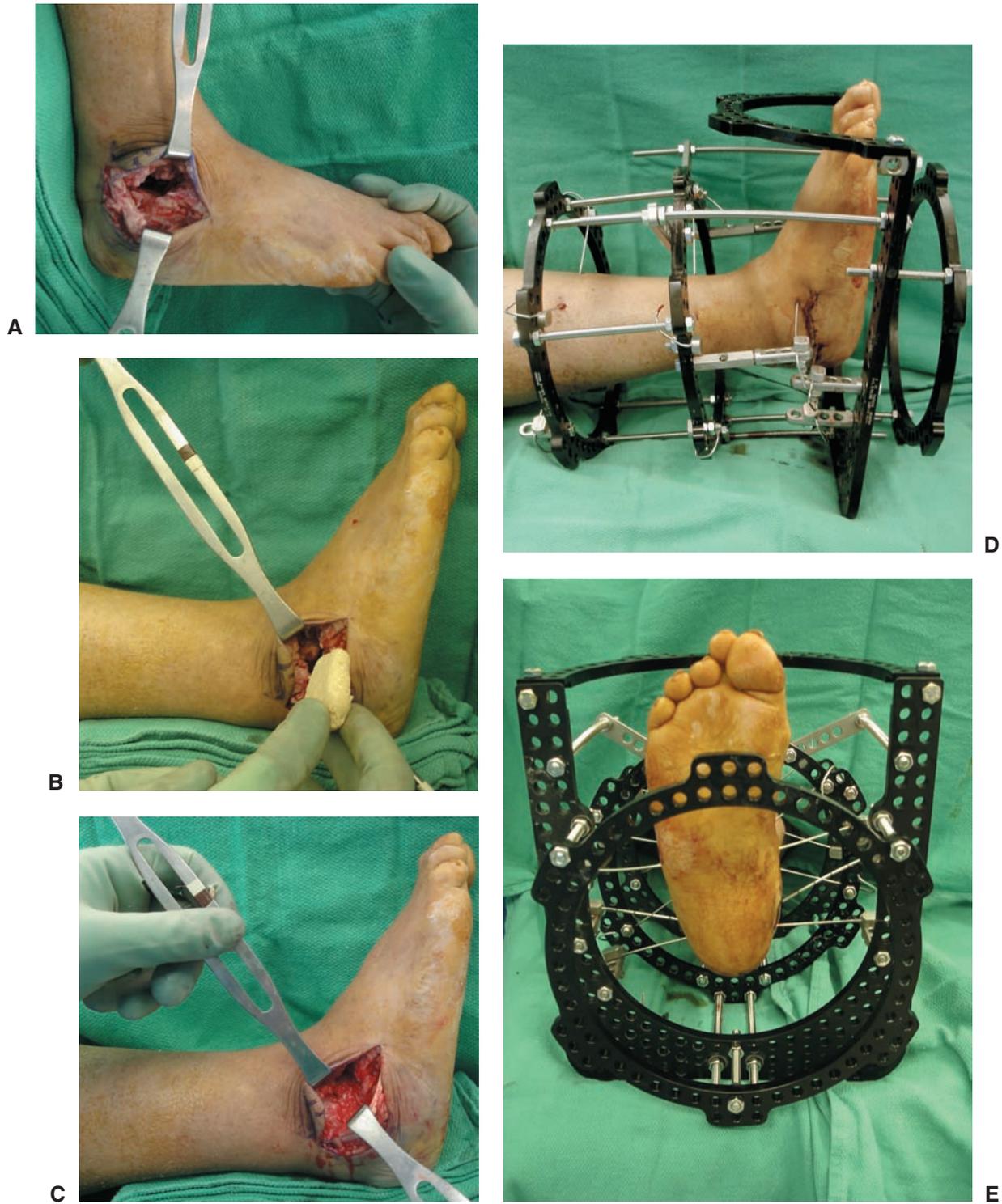
**Figure 25.5** Neuropathic technique for midfoot and forefoot pathology.



**Figure 25.6** Extra-articular calcaneal fracture repair. Distraction technique (**A,B**) followed by 3- to 4-cm skin incision directly over the subtalar joint (**C,D**), and application of corticocancellous allogenic bone grafting (**E**). Two transosseous calcaneal olive wires are placed from lateral to medial and tensioned from the medial side to 70- to 90-kg force (**F,G**). (*continued*)



**Figure 25.6** (Continued) A midfoot wire is placed from medial to lateral and tensioned to 70- to 90-kg force and an additional bottom ring is also applied to the foot plate for the initial 2 to 3 weeks for “weight-sharing” status (H-J).



**Figure 25.7** Intra-articular calcaneal fracture repair with primary subtalar joint arthrodesis. A 3- to 4-cm incision over the subtalar joint followed by the resection of the articular surface (A) and application of corticocancellous allogenic bone grafting (B,C). Please note the position of the talar wire for the subtalar joint arthrodesis and application of the circular external fixator (D,E). (continued)



**Figure 25.7** (Continued) Our preferred method of postoperative dressings are shown (F,G). Preoperative (H) and final postoperative (I) radiographs showing the primary subtalar joint arthrodesis procedure.

Lastly, ORIF with primary subtalar joint arthrodesis might also be considered in younger individuals in the early stages of diabetes mellitus (Fig. 25.8A–F). The postoperative course may be a minimum of 10 to 12 weeks of cast immobilization and/or the use of external electrical bone stimulation.

## POSTOPERATIVE MANAGEMENT

The estimated time for bony consolidation is approximately double the time normally estimated for a healthy patient. Prolonged stabilization is essential to prevent neuropathic fractures from progressing into an acute Charcot event.

The patient is kept in the hospital for 3 to 7 days postoperatively for glucose control, pain management, appropriate intravenous (IV) antibiotics, and to ensure that the patient is medically stable and able to rehabilitate before discharge. The patient receives 10 to 14 days of prophylactic low molecular weight heparin or other thrombolytic therapy, which is started 12 hours postoperatively and 7 to 10 days of oral antibiotics in accordance with the medical and infectious disease teams. The patient is seen weekly until the sutures and/or staples are removed at 3 to 4 weeks and then once every 2 weeks for the remaining months. Postoperative

radiographs are obtained at 2 to 4 weeks and then once a month until healing is complete. Patient and family care education, home health services, and close and constant monitoring are absolutely imperative.

The pin or wire sites are covered with gauze that is soaked with povidine-iodine (Betadine) and the external fixator is kept dry throughout the postoperative course. Patients are instructed not to take showers and are educated on pin or wire site care that is to be done weekly if necessary. Patient compliance is strongly emphasized and strict pin or wire site care must be maintained. Stability is also of the utmost importance. The wires and pins must be checked at each visit to guarantee that the tension has not been lost. Retensioning can be achieved using the manual tensioning technique.

## LISFRANC/FOREFOOT

The patient is kept non-weight-bearing for 10 to 14 days. The patient is then encouraged to be full weight-bearing as tolerated with assistance. A patient with diabetic neuropathy generally has consolidation at 8 to 14 weeks. The frame may be dynamized by loosening the tension from the wires. The patient is full weight-bearing for 2 weeks. If no problems occur,



**Figure 25.8** Preoperative radiographs (A,B) of an intra-articular calcaneal fracture, followed by a hybrid external fixator for distraction and stabilization (C) and a primary subtalar joint arthrodesis in this younger patient with diabetes mellitus (D-F).

the frame may be removed. The patient then progresses into a walking device for 4 to 6 weeks. After complete consolidation has occurred the patient requires custom molded inserts and/or ankle foot orthoses for extra support and to prevent future breakdown or collapse.

#### REARFOOT/MIDFOOT

The patient is kept non-weight-bearing for 10 to 14 days and then after this point the patient is encouraged to be full weight-bearing as tolerated with assistance. In a normal patient, bony consolidation normally takes 6 to 8 weeks. A patient with diabetic neuropathy generally has consolidation at 12 to 16 weeks. The patient is then encouraged to walk full weight-bearing for 2 weeks. If no problems occur the frame may be removed. The patient then progresses into a walking device for 4 to 6 weeks. After complete consolidation has occurred, the patient requires custom molded inserts and/or ankle foot orthoses for extra support and to prevent future breakdown or collapse.

#### CONCLUSION

The use of circular external fixation demands a great amount of surgical experience and training. The principles and techniques applied by circular external fixation are paramount to the management of complex neuropathic lower extremity

trauma and dislocations. However, extreme caution needs to be taken throughout the patient care. Postoperative complications are avoided by vast knowledge and training on external fixation and careful patient selection.

#### ACKNOWLEDGMENT

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