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Tips, Quips, and Pearls

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Technique for Minimally Invasive Reduction of Calcaneal Fractures Using Small Bilateral External Fixation

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ABSTRACT

Soft tissue complications are well known after extensile exposure of the calcaneus for open reduction internal fixation of fractures. A variety of recommendations have been proposed to reduce soft tissue healing issues and infection. Despite these recommendations, some surgeons believe that soft tissue complication rates have remained unacceptably high with lateral extensile incisions. Recently, interest in minimally invasive repair techniques for calcaneal fractures has increased. These techniques have been purported to avoid some of the common soft tissue problems seen with calcaneal open reduction internal fixation. The focus of the present communication is to share a minimally invasive surgical method for the reduction and fixation of calcaneal fractures. Percutaneous fixation of the posterior facet fragments can be facilitated by distraction of the fractured calcaneus using skeletal traction and a small bilateral external fixator. Final stability is achieved with a combination of the external fixator and percutaneous screws and/or wires. We present our technique and discuss recent published studies on minimally invasive repair of calcaneal fractures.

The treatment of displaced intra-articular calcaneal fractures is still a matter of some debate. Many surgical approaches and techniques of fixation have been used, with varying degrees of success. Most modern data have supported reduction of displaced calcaneal fractures and have reported improved function after reduction compared with no reduction (1–10). Many foot and ankle surgeons have preferred the extended lateral L incision approach with lateral plate fixation under direct visualization. However, the extensive soft tissue stripping required with this approach carries a high risk of soft tissue complications, including wound breakdown and infection, with published rates of 14% to 33% (11,12). In an effort to reduce the risk of such complications, a technique that indirectly reduces the calcaneus using external fixation was developed. We present this technique as an alternative to open reduction internal fixation of calcaneal fractures. We have used this technique successfully for the past 8 years.

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Surgical Technique

Surgical planning should begin with radiographic examination. Lateral, axial, and oblique views should be obtained for both feet. We have found it very helpful to use the views of the uninjured calcaneus as a map for reconstruction of the fractured calcaneus. Multiplanar computed tomography scans will also be helpful to understand the details of the posterior facet fragments and plan the reduction and fixation. The patient should be medically evaluated for anesthetic risk and their medical status optimized before surgery. Other orthopedic injuries should be evaluated and addressed, as necessary. Unlike open reduction internal fixation of calcaneal fractures, this minimally invasive technique does not require a delay in surgery for a reduction of edema. Acute reduction is preferred before the induration and contracture of the local soft tissues. The procedure can be performed with the patient under general or spinal anesthesia, which should be selected in accordance with medical concerns and/or patient preference. Complete relaxation of the extremity is necessary to obtain reduction using indirect methods. The patient should be placed on the operating table in a supine position and the hip of the affected limb "bumped" to position the operative foot neutral in the frontal plane. Intraoperative fluoroscopy should be used throughout the reduction

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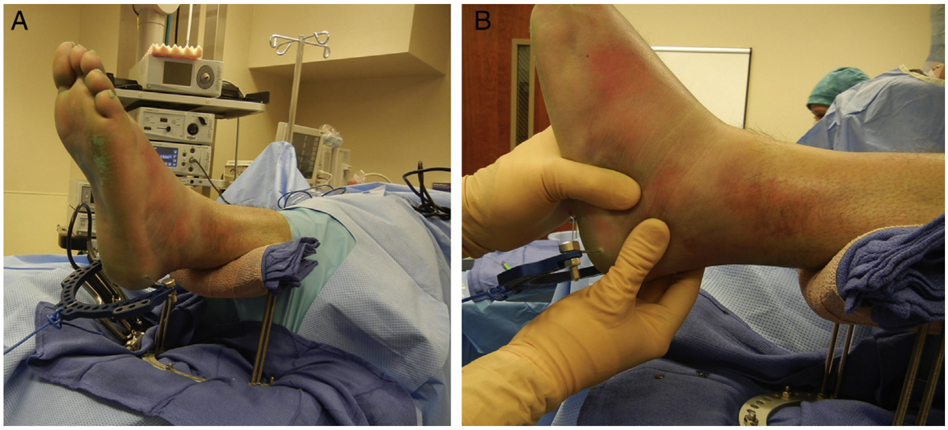

Fig. 1. (*A*) Application of skeletal traction for indirect reduction of calcaneal fragments. The application of the traction force should be as close to the natural inclination angle of the calcaneus as possible. (*B*) In most cases, a varus position and shortening are both easily reduced with manual manipulation after 5 to 10 minutes of sustained traction.

procedure. Standard surgical site preparation should be used and a prophylactic antibiotic administered before the procedure, according to the medical center protocol.

Step 1: Application of Skeletal Traction and Indirect Reduction

Sustained skeletal traction is a vital component of this method (Fig. 1). Regaining the length of the calcaneus and thereby dis-impacting the central fragments facilitates fracture fragment reduction and fixation. “Skinny wire” traction is preferred to preserve the posterior tuber for later insertion of the half pins for the fixator. The wires require very little space compared with traction pins and, in many cases, allow half pin placement before the release of traction. A smooth Kirschner wire or 1.8-mm skinny wire is inserted transversely through the posterior aspect of the calcaneus and connected to a half ring. Tensioning of the traction wire can be accomplished using the “Russian” technique. A 20- to 25-lb weight is applied to the traction device and maintained for 5 to 10 minutes. It is desirable to obtain the proper length of the calcaneus and reduce all varus of the posterior calcaneus before placement of the fixator half pins. This avoids the skin tension that can develop between the half pins if the fixator is used for distraction. An approximately 20° to 40° angle of the traction rope, directed downward from the long axis of the limb, would be optimal. The angle of the traction rope should approximate the natural inclination of the calcaneus to pull the tuber out to length and in a plantar direction. Raising the operating room table and placing the patient in the Trendelenburg position can aid in achieving the desired angle. With relaxation of the soft tissues, a reduction of the calcaneal tuberosity can be achieved. The varus position and shortening are easily reduced with both skeletal traction and additional manual manipulation. Once the tuber has been reduced to nearly the anatomic position, the half pins should be placed before the release of the traction. If several days have passed since the fracture, longer periods of traction could be required to relax the indurated soft tissues and pull the fracture fragments out to length.

Step 2: Placement of Talar and Calcaneal Half Pins

Threaded half pins, usually 4 mm, should be inserted into the center of the talar neck and the most posterior part of the calcaneal tuberosity (Fig. 2). The medial talar and calcaneal pins should always be inserted first to prevent the recurrence of varus. The half pins should all be inserted bicortically, using accepted pin insertion techniques according to the pin type. Two half pins, engaging 2 cortices each (4 cortices), are preferred to transosseous pins in the calcaneus. We have found the opposing half pin construct to be more stable and much more durable than a single transosseous pin. It has been helpful to place the calcaneal tuber pins in a slightly plantar direction to achieve the proper angle for reduction. A connecting rod can be used to connect the half pins to maintain reduction of the tuber fragment. In some cases, 2 half pins in the medial side of the calcaneal tuber can be used to increase stability. Once the varus has been reduced and stabilized, lateral half pins should be inserted into the talar neck and the calcaneal tuberosity. If the anterior facet of the calcaneus has also fractured, the addition of a half pin in the cuboid can be used to distract or reduce the fracture. As noted, bicortical insertion is vital for stability and durability. Transosseous pins should never be used. Care is needed to place the talar neck pins in the center of the talar neck. The pins should normally be placed 1 to 1.5 cm from the talonavicular joint. Calcaneal pins should be placed as far posterior as possible to engage the more solid and stable portion of the calcaneal tuber. If increased stability is desired, additional half pins and connecting rods can be used. The angle of pin insertion can also be varied to aid in reduction. Once both the medial and the lateral constructs are in place, the fracture reduction can be refined by progressive distraction and/or release of the components. If excessive tension occurs, the skin should be released at the far side of the pin.

Step 3: Reduction of the Posterior Facet

Indirect reduction can be achieved by ligamentotaxis with distraction of the anterior and posterior components (Figs. 3 to 5). In most cases, direct reduction the posterior facet will be needed and can be achieved either percutaneously or through limited incisions. It is vital to have the calcaneus fully distracted to its anatomic length and the varus reduced before attempting reduction of the posterior facet. The fracture fragments will not move freely if the calcaneus is still impacted. Final stabilization of the posterior facet can be performed with pins or screws. Because the fixator is spanning the fractures, the forces of displacement acting on the fragments will be fewer, and, therefore, less rigid fixation will be acceptable. We most commonly use smooth pins for stabilization and remove them at frame removal. Once the calcaneal tuber has been brought downward, pulled out to length, and the varus reduced, the posterior facet fragments have been partially reduced by indirect and ligament forces. A final reduction of the facets can be directly obtained as shown in Figs. 3 to 5. The fragments can be reduced and fixated through small incisions. We have found the sinus tarsi approach helpful to provide direct

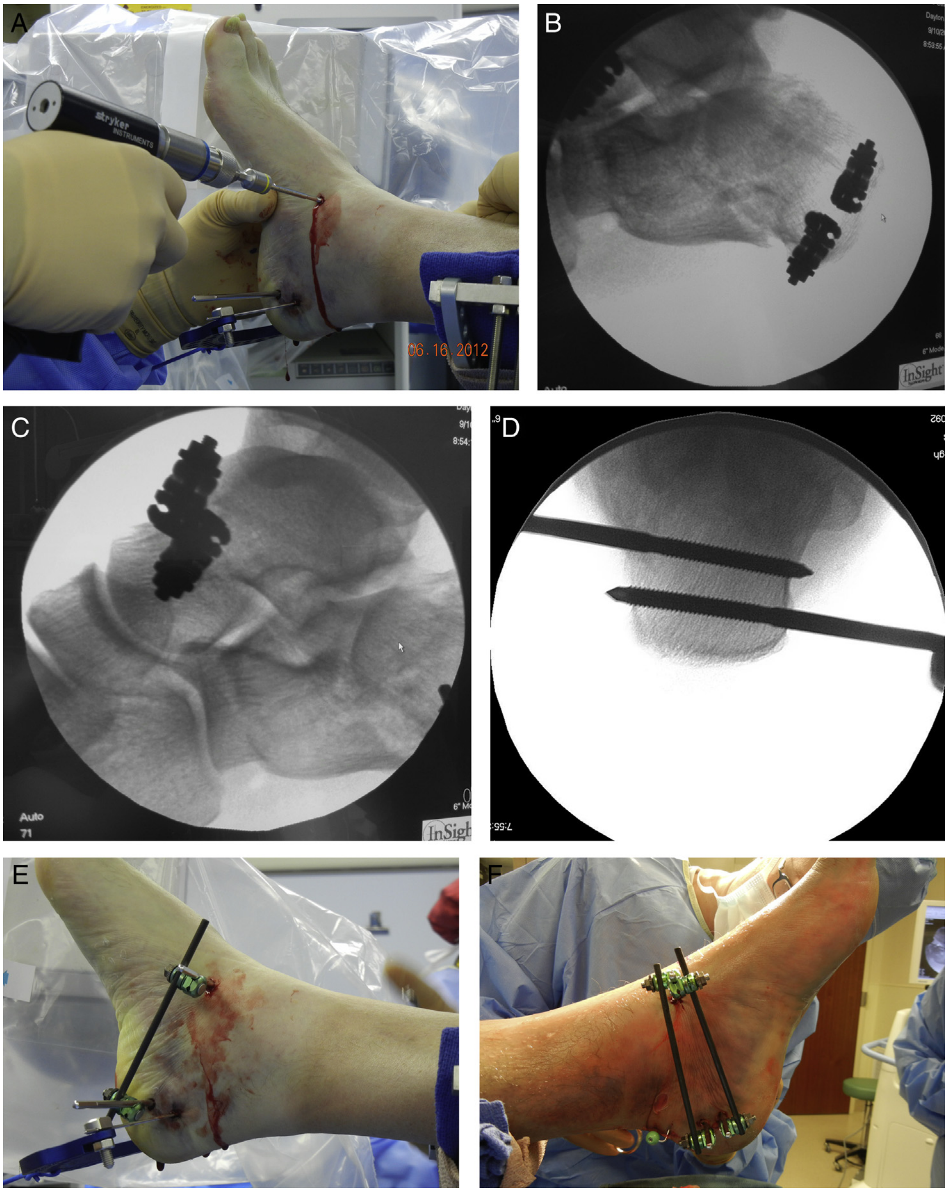

Fig. 2. (*A*) Threaded half pins are inserted into the center of the talar neck and the posterior calcaneal tuberosity. The medial talar and calcaneal pins should be inserted first to reduce the varus component. (*B*) Placement of the calcaneal pins should be as far posterior as possible to engage the more solid, stable portion of the calcaneal tuber. (*C*) Placement of the talar pins should be as close to the center of the talar neck as possible. Note, the arthrodiastasis of the subtalar joint. (*D*) Enhanced stability and durability can be achieved by 2 half pins engaging 2 cortices each in the calcaneus and talus. (*E*) Once the medial and lateral constructs are in place, the fracture reduction can be refined by progressive distraction and/or release of the components. (*F*) If increased stability is desired, additional half pins and connecting rods can be used.

visualization of the posterior facet for reduction. Transcutaneous wires and/or small cannulated screws can be used for final fixation. Lateral and calcaneal axial fluoroscopic projections should be repeated throughout the procedure to ensure proper positioning of the calcaneus.

Several different methods of posterior facet reduction can be used. It should be emphasized that before the reduction of the facets, the frame should be in place with the calcaneal length and rotation reduced. The fragments will be difficult, if not impossible, to reduce unless the central portion has been decompressed. A small lateral incision can be used to directly manipulate the fragments back into position and hold them for fixation (Fig. 3). A blunt probe can be placed through a small incision on the bottom of the foot and advanced through the primary fracture line to push the pieces of the facet up to the talus and hold them while smooth Kirschner wires or cannulated screws are introduced (Fig. 4). A pin or wire can be used from the posterior direction to lever the fragments back into place (Fig. 5). Many times, a combination of reduction maneuvers will be necessary to obtain satisfactory alignment. After using any of these reduction methods, the fragments can be stabilized percutaneously with combinations of wires, screws, or subcutaneously inserted small plates, depending on the fragment pattern.

Step 4: Postoperative Regimen

A stable frame construct is the most important factor in the avoidance of pin complications for all external fixation applications. Motion and instability have been the most common reason the pins become irritated and infected. Stable fixator application and excellent pin insertion technique are the first step in pin care.

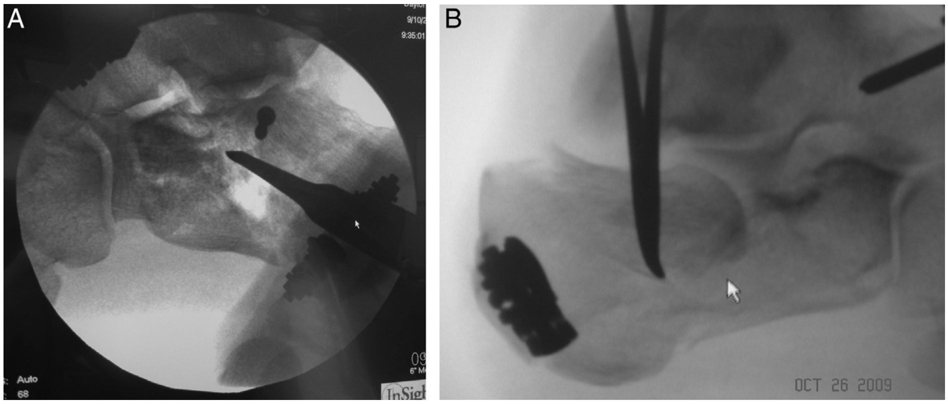

Fig. 3. (*A*) A small lateral incision or sinus tarsi incision can be used to directly manipulate the fragments back into position and temporarily maintain their position until fixated. (*B*) Technique for direct manipulation of the fragments through a lateral incision.

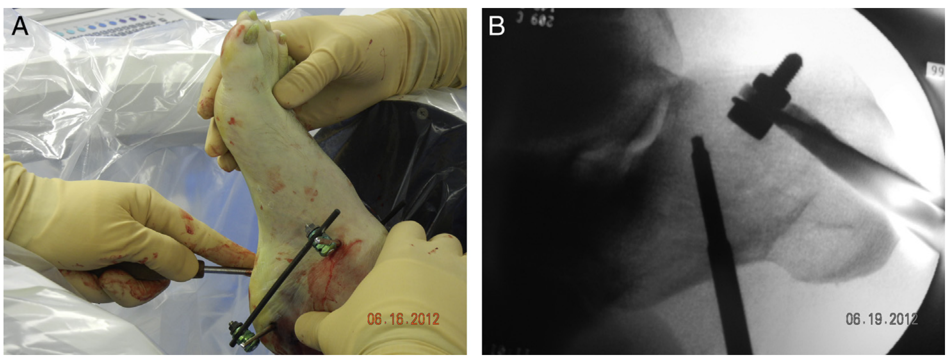

Fig. 4. (*A*) A blunt probe can be placed through a small incision on the bottom of the foot and advanced through the primary fracture line to push the pieces of the posterior facet up to match the talus. (*B*) Reduction of the posterior facet using a blunt probe advanced through the primary fracture line.

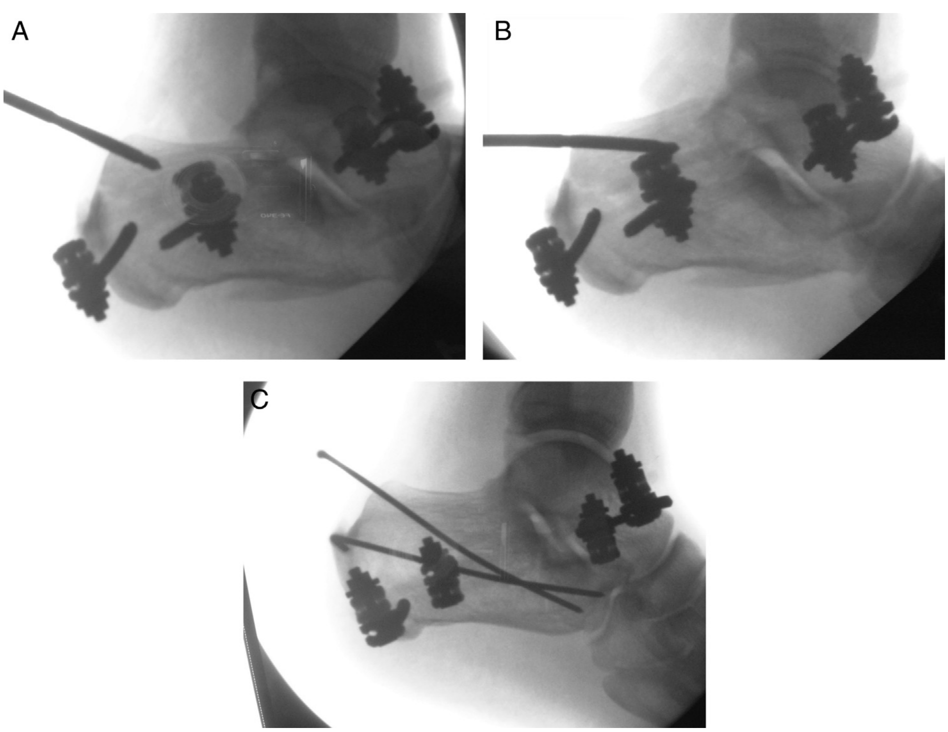

Fig. 5. (*A* and *B*) In certain instances, percutaneous reduction of a fragment can be achieved using a pin as a lever. (*C*) Percutaneous placement of smooth Kirschner wires provides stable fixation of the fragments.

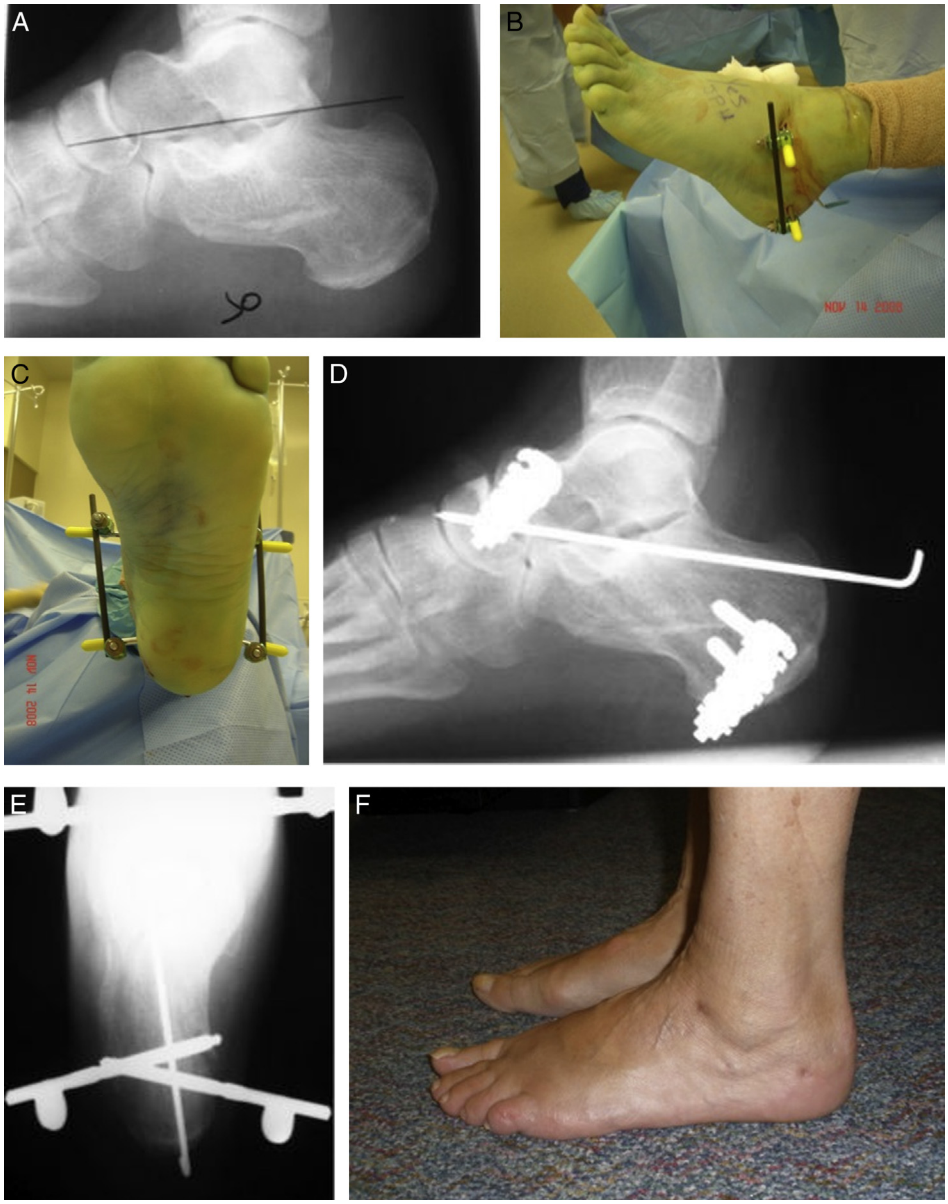

Fig. 6. Case 1. (*A*) Lateral radiograph of a 40-year-old female with a calcaneal fracture and decreased Bohler's angle. (*B*) Typical half pin and bar placement on the lateral side after reduction of the major components of the calcaneus by skeletal traction. (*C*) Medial and lateral frame constructs. (*D*) Note the reduction of Bohler's angle and the restored length of the calcaneus. The Kirschner wire maintains the reduction of the posterior facet. The position is easily maintained owing to the distraction of the fragments and posterior facet with stable bilateral external fixation. (*E*) Reduction of the varus position. Note, the half pin placement with 2 bicortical half pins. (*F*) Three-month postoperative view showing the benefit of minimal soft tissue disruption, with almost invisible lateral pin sites, no swelling, and minimal soft tissue scarring.

Compression sponges should be used between the frame components and the skin to stabilize the pin–skin interfaces. The compression sponges should generally be left intact for 4 to 7 days and then removed. Our preferred postoperative regimen has included a daily shower to cleanse the operative foot and all the frame components. The patient should be instructed to shower daily, including washing the fixator and foot and then replacing the sponges at each of the pins. No topical medications, hydrogen peroxide, or other pharmaceutical agents should be used on the pins or frame components. The patients should be evaluated weekly and radiographs taken at 2- to 3-week intervals. The frame can be removed radiographic evidence of fracture gap filling is present. This usually occurs at 8 to 12 weeks. The patient should be encouraged to maintain ankle and leg range of motion throughout the day. Weight bearing on the operative foot should be forbidden throughout recovery until the frame has been removed. Patient examples are shown in Figs. 6 to 8.

Discussion

The treatment of displaced intra-articular calcaneal fractures is still a matter of some debate. Many surgical approaches and techniques of fixation have been used, with varying success. We believe confusion remains regarding whether it is restoration of the posterior facet that improves functional outcome or whether function is improved by overall 3-dimensional calcaneal reduction. Most modern data have supported reduction of displaced calcaneal fractures and indicated improved function after reduction (1–10). Much has been

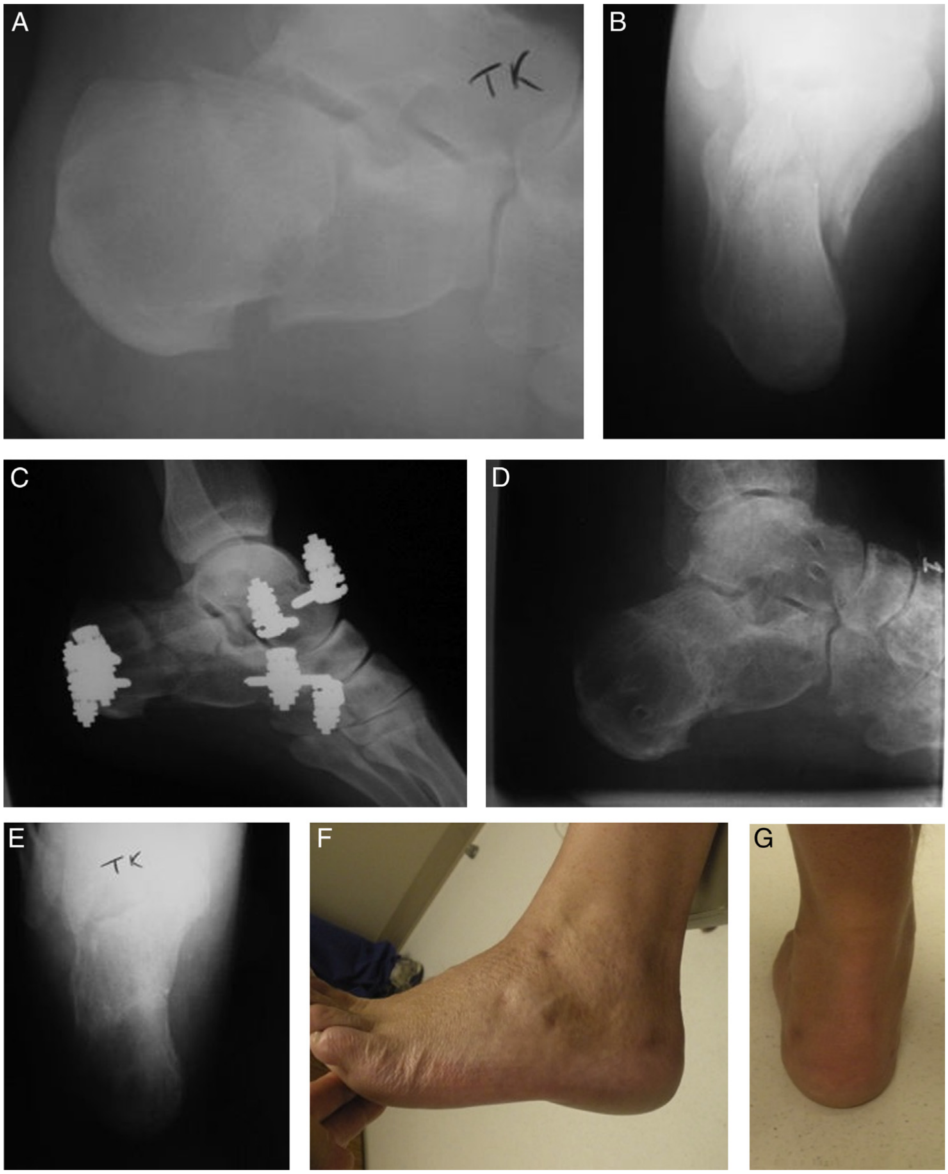

Fig. 7. Case 2. (*A* and *B*) Calcaneal fracture radiographs showing joint depression, shortening, and severe varus position of the posterior calcaneus. (*C*) The length has been restored, varus position reduced, and stabilization provided with bilateral external fixation. (*D*) The fracture has been reduced, and radiographic evidence of healing at 8 weeks after reduction just after frame removal. (*E*) Calcaneal axial radiograph showing reduction and healing of the calcaneus in anatomic position. (*F* and *G*) Clinical evidence of excellent soft tissue healing, a normal clinical position, and minimal scarring at 4 months after reduction.

stated regarding posterior facet reduction and subtalar range of motion. The principles of intra-articular fracture management have been determined by restoration of the joint surfaces, with early rehabilitation of motion. However, when we consider the function of the calcaneus regarding the weight bearing interaction with the midfoot and ankle, the overall position of the calcaneus in 3-dimensional space is extremely important. We know that the foot and ankle both will be severely affected by abnormal forces generated by a varus heel. A varus-positioned calcaneus produces pronatory compensation of the midfoot and applies valgus stress to the ankle. Similarly, the shortened, proximally migrated heel often seen with a calcaneal fracture will induce significant anterior loading forces on the ankle and can effectively weaken the posterior muscle pull. A wide calcaneus is well known to cause peroneal tendon impingement. We believe it is the overall structural alignment of the calcaneus that is the priority and that the structural alignment is important for foot and ankle function. The posterior facet is certainly a factor in reconstruction and ultimate function but might not necessarily be the most important factor.

The external fixation method we have described has the ability to position the posterior calcaneus anatomically. Varus can be easily reduced, and the posterior calcaneus can be brought down and out to the correct length better than with all the other methods we have tried. With the components of the body reduced and the central calcaneus spanned by the fixator, the posterior facet fragments become much easier to reduce. The fragments will move back into position because space has been created by traction and arthrodiastasis. The initial traction will reduce the fragments, and the fixator will maintain the calcaneal body components, allowing reduction of the facets.

Additionally, we believe the arthrodiastasis produced by the fixator spanning the subtalar joint will be protective of the cartilage

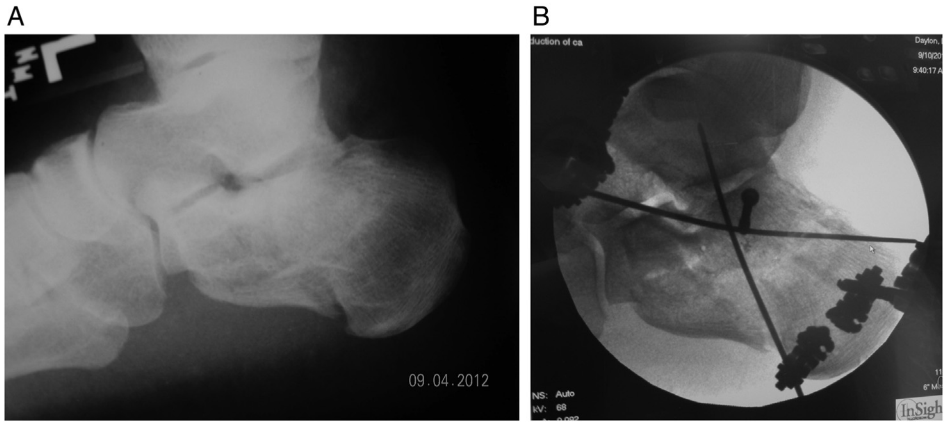

Fig. 8. Case 3. (*A*) Joint depression calcaneal fracture with shortening of the body and disruption of the posterior facet. (*B*) Fluoroscopic image showing restoration of calcaneal body length, subtalar arthrodiastasis, and posterior facet reduction with a percutaneously placed screw and smooth Kirschner wires.

surfaces and the periarticular soft tissue. By removing the compressive forces from the subtalar joint, the position of the facet fragments can be easily maintained, with limited fixation. The joint surfaces and cartilage are unloaded and protected. At the same time, the ankle will remain mobile for range of motion exercises.

It has become a standard recommendation to delay open reduction to allow the soft tissues to recover from the trauma. This is similar to the recommendation for delayed reduction in other high-energy extremity trauma, such as pilon fractures. With indirect reduction and external fixation, the surgical trauma to the soft tissues will be much less. Thus, our procedure does not necessarily need to be delayed. We have found it easier to manipulate the fracture fragments without the waiting period that results in induration and tightening of the tissue. We have noted exceptionally low rates of soft tissue complications with this method. Other investigators have also noted favorable complication rates with a variety of minimally invasive techniques (13–19).

Our experience with this minimally technique for the reduction and stabilization of calcaneal fractures has been similar to published reports. The return to function in our patients has been similar or better than after open reduction, and our soft tissue complication rate has been much lower. The goal of our method is to provide anatomic reduction without the need for extensile exposure and can be achieved with careful attention to external fixation principles. Additional prospective outcomes studies and comparison studies are needed to further clarify the safest and most effective reduction techniques.

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