CHAPTER **59**

TREATMENT OF INTRAARTICULAR CALCANEAL FRACTURES WITH MINIMAL OPEN REDUCTION AND EXTERNAL RING FIXATION

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The calcaneus is the most commonly fractured bone in the adult foot, accounting for approximately 60% of all foot fractures and up to 2% of all skeletal fractures. In adults, the calcaneal bone is susceptible to axial loading, which is caused by a fall from a height or a motor vehicle accident. The result can be compression and displacement of the fracture fragments. In the adult population, up to 70 – 75% of calcaneal fractures are intraarticular with the remaining 25 – 30% extra-articular. Intra-articular calcaneal fractures are very serious injuries and can be severely disabling. The most commonly involved area is the posterior facet of the subtalar joint. The generally accepted treatment for displaced intraarticular calcaneal fractures is open reduction and internal fixation. The employment of open reduction and internal fixation may be contraindicated in instances such as severe comminution and soft tissue disruption. It has also proven to be a technically difficult procedure having a limited ability to anatomically reproduce alignment of the subtalar joint and the shape of the calcaneus. The patient is generally kept non-weight bearing for a minimum of 6 – 8 weeks. Alternatively, closed methods of reduction do not address anatomical restoration and can result in significant residual pain and thus functional limitations. The authors propose the use of tensioned wires attached to an external ring fixator for the treatment of intraarticular calcaneal fractures. The fixator is used to manipulate the fracture fragments in a closed fashion and then to stabilize the fragments once reduced. If necessary, a minimal incision open reduction approach is employed to reduce a displaced posterior facet. The patient is encouraged to be ambulatory on the first postoperative day. Ultimately, restoration of the width, length and height of the calcaneus is achieved along with anatomic realignment of the posterior facet.

RADIOLOGY AND CLASSIFICATION

Plain radiographs provide the initial fracture anatomy and include anteroposterior (AP), oblique and lateral views of the foot and a Harris axial view. The AP and oblique views help to define the extent of the fracture into the calcaneocuboid joint. The fracture is easiest to visualize on a lateral view, as is the loss of height of the posterior facet. In addition, the lateral view will demonstrate a decrease of Bohler's angle (25° – 40°) and an increase in the Critical angle of Gissane (125° – 140°). The axial view helps to visualize the posterior facet region but more importantly, it demonstrates any varus or valgus position of the tuberosity, the presence and amount of medial wall comminution and the location of the primary fracture line. These four views allow one to define most of the fracture anatomy and access the three-dimensional relationship of the fragments to one another.[1] When the plain film radiographs fail to show complete definition of the fracture anatomy, especially when an intra-articular fracture is suspected, the use of computed tomography (CT) is indicated. CT provides details of the joint alignment and the extent of the intraarticular fracture relationships that plain films do not demonstrate.[2,3,4] The CT scans should be obtained in both axial and coronal planes.

Ideally, any fracture classification should help to guide treatment, provide a general estimate of the prognosis and allow accurate comparison of fractures after treatment. Classification of intraarticular fractures has been well documented.[5-11] Currently the most widely used and useful classification scheme is that of Sanders and is based upon the number and location of articular fracture fragments as viewed on CT sections in the axial and coronal planes.[12] Type I fractures include all non-displaced articular fractures regardless of the number of fracture lines. Type IIA, IIB and IIC fractures are two-part fractures of the posterior facet and are distinguished by the location of the primary fracture line. Type IIIAB, IIIAC and IIIBC fractures are three-part fractures with a central depression and are based upon the location of the primary fracture line. Type IV fractures are highly comminuted with at least four fragments.[12]

METHODS

From 1995 to present, 23 patients (19 male, 4 female) with 25 intraarticular calcaneal fractures were treated with minimal open reduction and external ring fixation. Two patients had bilateral fractures. Sixteen fractures (64%) resulted from a fall from a height, five (20%) from a motor vehicle accident and four (16%) from indirect trauma. The fractures were classified using Sanders CT classification and were as follows: 17 (68%) Type II, six (24%) Type III and two (8%) Type IV.

Appropriate radiographic examination was performed preoperatively and included AP, lateral, oblique and axial views. CT scans were also obtained in the coronal and axial planes. In the event that surgery was delayed due to the medical condition of the patient, a Jones compressive bandage was utilized to help control edema and the patient was placed on complete bed rest. After the patient was deemed medically stabile surgery was performed regardless of the amount of swelling associated with the fracture. External ring fixation was applied to all patients in conjunction with minimal open reduction. Standard postoperative radiographs were obtained during follow-up evaluations. Mean fixator duration was 6.6 weeks (range 6-9 weeks). The longest follow-up to date is 8 years.

Figure 1A. Lateral view of the foot demonstrating fracture pattern of the calcaneus. A decrease of Bohler's angle is evident as is a "double density" sign indicating depression of the posterior facet.

OPERATIVE TECHNIQUE

Preoperative planning begins with evaluation of radiographs and CT scans (Figure 1A, 1B). General indications for surgical intervention include a greater than 2mm displacement of the posterior facet and disruption of the length, width and height of the calcaneus. Particular attention must be paid to an increase in the width of the calcaneus as this can lead to postoperative calcaneofibular impingement. Of primary importance is determining the amount of comminution and displacement of the posterior facet of the subtalar joint, as well as the body of the calcaneus.

The extremity to which the procedure will be performed is prepped and draped to the knee. A pre-assembled frame consisting of two leg rings and a footplate are placed on the affected extremity (Figure 2A, 2B). A half-pin is driven transversely through the posterior aspect of the calcaneus to which is applied skeletal traction using 30 – 40 lbs (Figure 3). Placement of this pin should not interfere with the ability to later place wires on either side of the calcaneal bone. The force of the fracture reduction through traction should be directed posteriorly and distally. The goal with traction is to reestablish, as anatomically as possible, the length and height of the calcaneus. In so doing, deviations of Bohler's angle (normal $25^\circ - 40^\circ$) and the Critical angle of Gissane (normal $125^\circ - 140^\circ$) are also being addressed. Also, while traction is being applied, the width of the fractured bone can often be reduced through manual compression on both sides of the calcaneus.

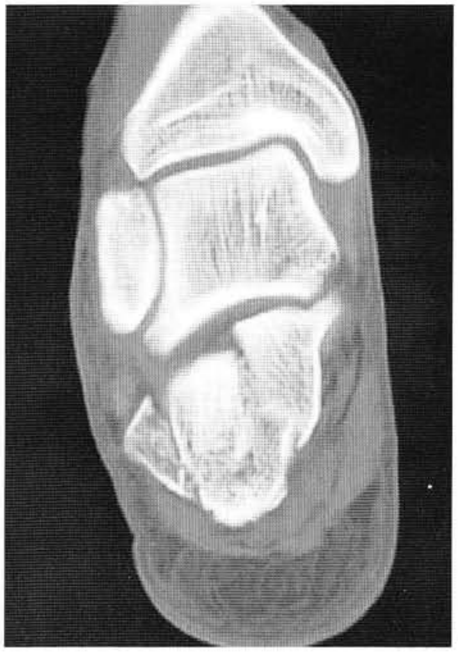


Figure 1B. Computed tomography (CT) reveals the extent of intraarticular involvement.

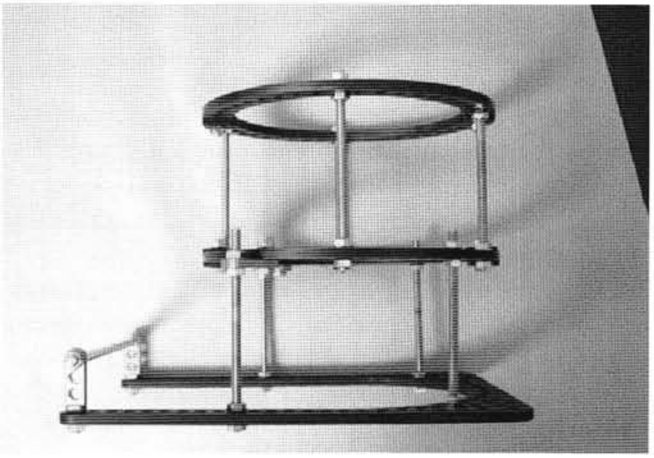


Figure 2A. Lateral view of the pre-assembled frame with two tibial rings and a footplate.

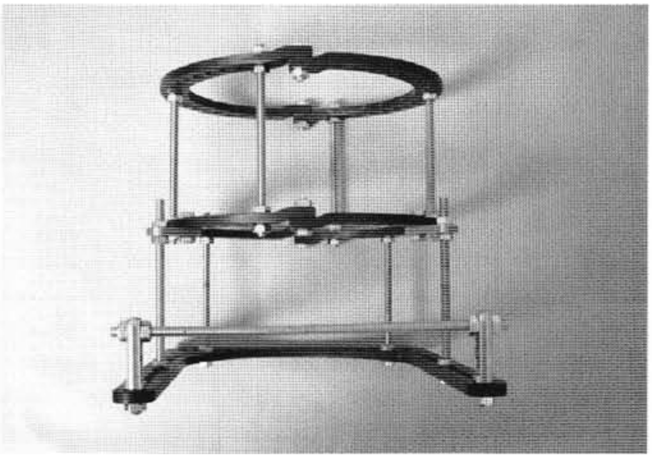


Figure 2B. AP view of the frame.

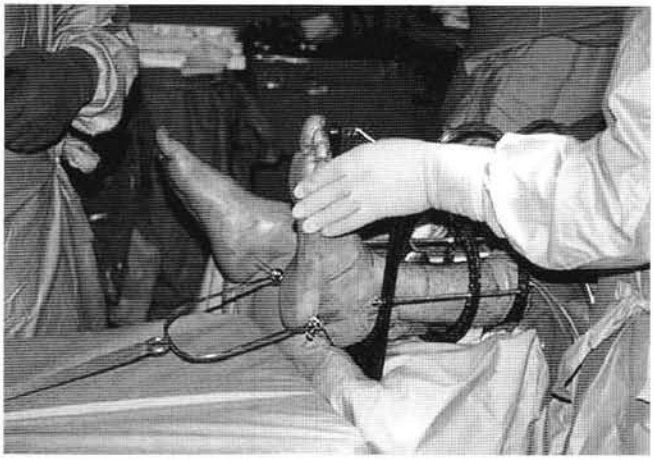


Figure 3. Skeletal traction being applied to the affected lower extremity with a transverse Steinman pin thru the calcaneus. The goal is to restore length and height of the fractured bone.

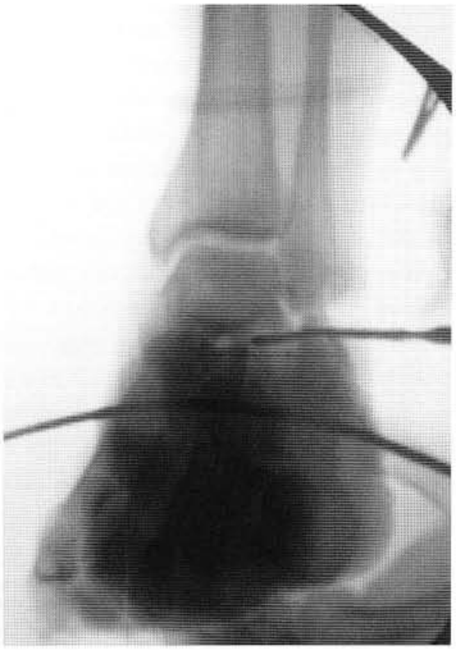
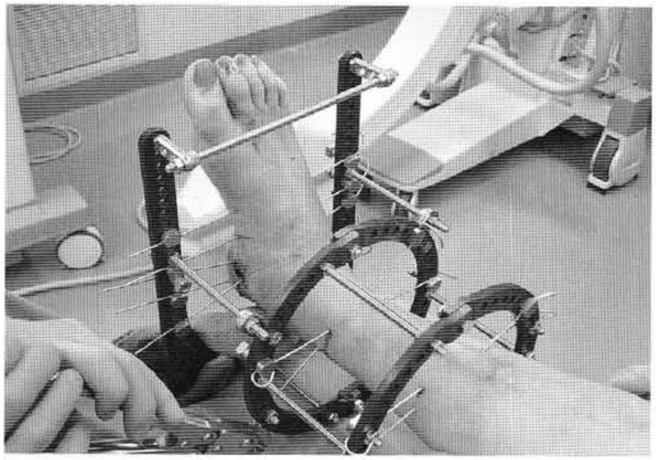


Figure 4. A minimally invasive technique to disimpact and restore position to a depressed posterior facet – under image intensification a freer elevator is placed through a small lateral incision and the fragment is elevated.

Following adequate reduction, a fluoroscopic Brodens view is obtained which clearly visualizes the posterior facet.[13] If necessary, a small incision is made inferior to the lateral malleolus, into which a freer elevator is placed, under fluoroscopy, with the aim of repositioning any displaced fracture fragment of the posterior facet (Figure 4).

The frame is then attached to the extremity in the following manner. A frontal plane smooth wire is placed into the tibia at the level of the proximal ring. With the frame eccentrically positioned on the leg and foot, so that the frame is approximately two finger widths from the leg anteriorly, the wire is fixed to the ring and tensioned to 130 kg. Another smooth wire is placed transversely into the calcaneus, fixed to the footplate and tensioned to 60 kg. Three additional tibial wires are added, as above, to make two wires per ring. Under fluoroscopy, two additional smooth wires are inserted from lateral to medial through the midfoot and are fixed to the footplate with 60 kg of tension. These wires help to maintain the foot in a 90° position to the leg (Figure 5A, 5B). As needed, additional wires including olive wires with washers can be placed from opposing directions to further reduce and/or maintain the reduction of the calcaneal width. Distraction of the subtalar joint is then carried out by increasing the distance between the footplate and the most distal tibial ring. This is achieved by loosening the nuts on the dorsal side of the ring and tightening the nuts on its plantar side



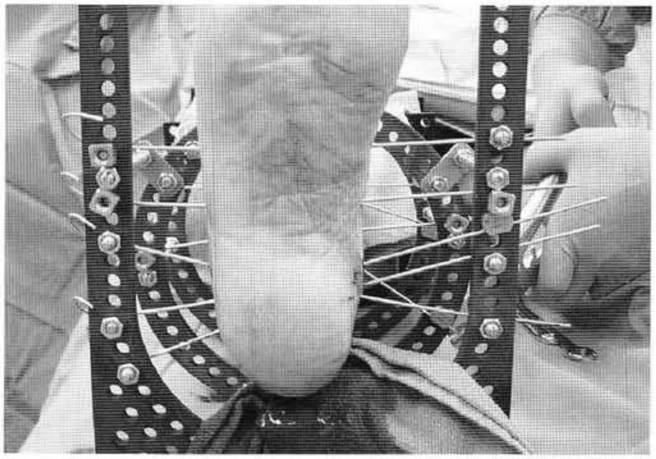


Figure 5A, 5B. Position of the foot and leg within the frame; the foot is 90° to the leg.

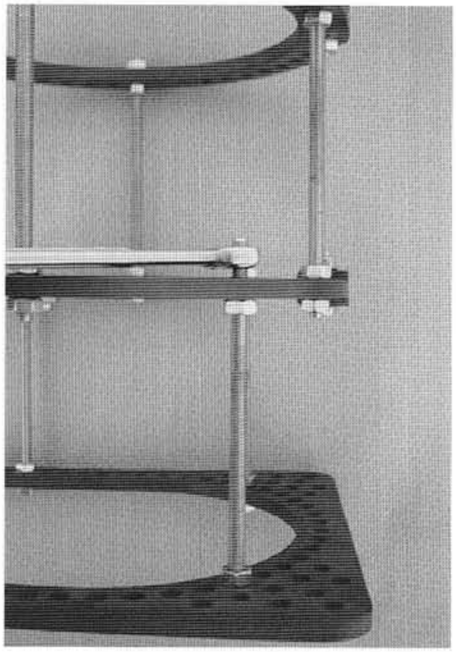


Figure 6A. Distration of the subtalar joint is achieved by increasing the distance between the distal tibial ring and the footplate; (a) loosen the nut on the dorsal side of the ring, and (b) tighten the nut on its plantar side.

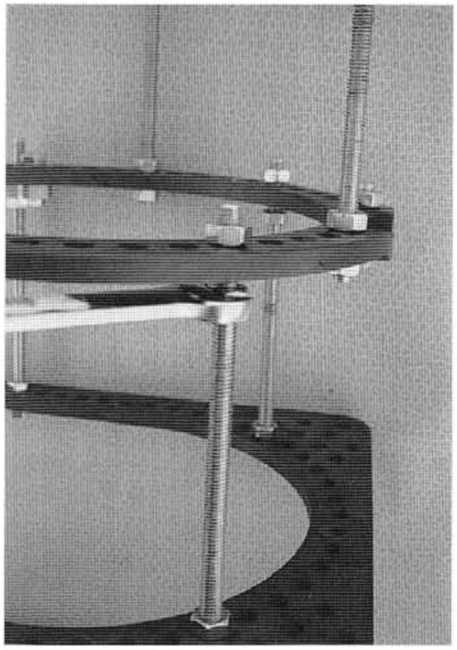


Figure 6B.

(Figure 6A, 6B). Fluoroscopic evaluation of the final fracture reduction is then made and if satisfactory skeletal traction is then removed from the extremity.

Beginning on the first postoperative day the patient is encouraged to ambulate to tolerance. On average, the frame is in place for 6 – 8 weeks. Upon its removal, the patient is placed in a cam-walker for 2 – 3 weeks. The patient is then allowed to bear weight unprotected and begins physical therapy to improve ankle and subtalar ranges of motion.

RESULTS

All patients were able to be at least partially weight bearing during the treatment period. Two-thirds of the patients used crutches and one-third, walkers. The two patients with bilateral calcaneal fractures initially used walkers but by the third week were able to use crutches. Treatment time ranged from 6 – 9 weeks with a mean of 6.6 weeks.

Figure 7A. Pre-operative lateral radiograph of a 37-year-old male, who fell from a scaffold, revealing an intraarticular fracture of the calcaneus with depression of the posterior facet.

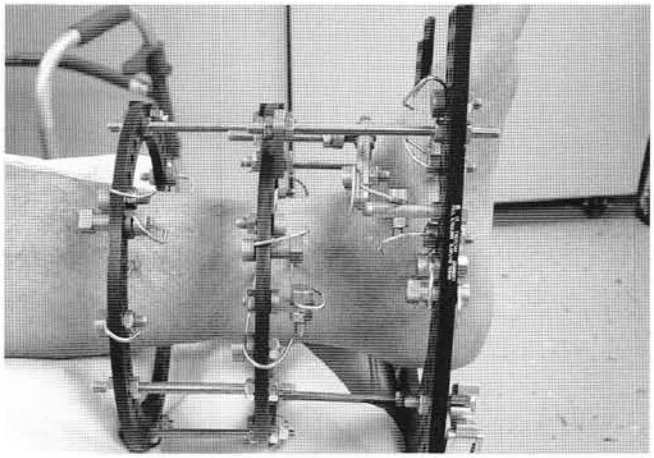


Figure 7B. View of the applied apparatus during treatment.

Subjective and objective clinical evaluation was performed on all patients using the Maryland Foot Score, according to which results are categorized as excellent (90-100), good (75-89), fair (50 – 74) and poor (<50).[14] Thus, eight of the 25 (32%) fractures rated as excellent. In these patients, subtalar range of motion was greater than 50% and they experienced mild pain that was related as diminishing with time and tolerable. Fifteen (60%) fractures rated as good. Subtalar joint range of motion was also greater than 50% but they had somewhat more persistent diffuse pain that patients related as non-diminishing with time, but was still tolerable. Two (8%) fractures rated as fair due to a less than 50% range of motion of the subtalar joint and chronic pain, especially with prolonged ambulation. These two patients had unilateral intraarticular calcaneal fractures that resulted from a fall from a height. Both subsequently reported pain in bilateral lower extremities. Nerve conduction studies demonstrated prolonged nerve latency as result of nerve compression at the L4 – L5 – S1 lumbosacral vertebral levels. These patients were treated conservatively by a consulted physician, which resulted in subsidence of their foot and leg pain to tolerable levels.

No patient experienced any failure of hardware, nor was any intolerance of the fixator observed. Five patients developed a superficial skin infection at a wire insertion site. None required the removal of a wire. No patient had evidence of fibulo-calcaneal impingment or increased heel width. None had plantar heel pain. To date, none of the patients has required further surgical intervention. All are ambulating in normal shoe gear and able to perform daily activities. Illustrated cases are portrayed in Figures 7-9.

Figure 7C. Post-operative lateral radiograph demonstrating restoration of posterior facet.

DISCUSSION

Intraarticular fractures require anatomic reduction and stable fixation in order to improve the chances of a good outcome.[15] Traditional methods of open reduction and internal fixation can be contraindicated in certain situations such as fractures with a high degree of comminution and soft tissue disruption. One of the principles of internal fixation is early range of motion, however, in regards to fractures of the calcaneus, early range of motion does not mean early weight bearing. It

Figure 8A. Pre-operative lateral radiograph of a 2-year-old female, who fell from a step-ladder, reveals an intraarticular fracture with a decrease in Bohler's angle.

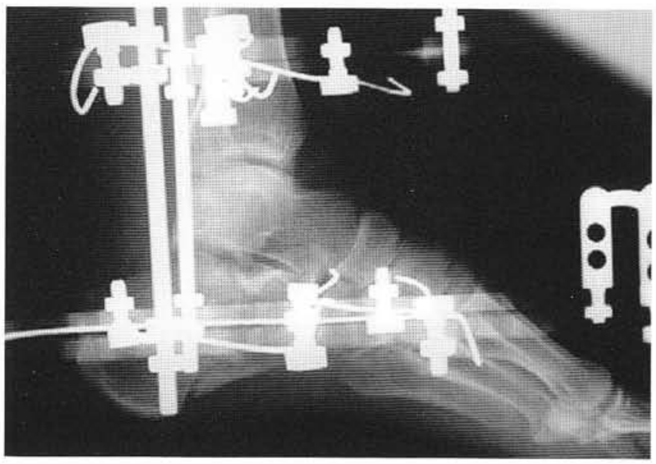


Figure 8C. Post reduction lateral radiograph demonstrating the restoration of the anatomic alignment. Distraction of the subtalar joint is achieved with the external fixator.

has been observed that non-weight bearing with early range of motion does not necessarily ensure good outcome and may in fact result in significant residual pain, especially in the plantar heel.[16] The benefits of early weight bearing, as demonstrated by Paley and Fischgrund in six of seven patients who underwent anatomic restoration of the subtalar joint and heel with circular external fixation, can help to ensure an improved outcome.[16] They found that through early weight bearing the plantar heel fat pad was desensitized and thus helped to prevent chronic heel pad pain and dystrophy.[16]

Besides permitting early weight bearing, another unique feature of external ring fixation is that it allows distraction of the calcaneus at the subtalar joint. This may help to prevent soft tissue contracture during the period of immobilization, which could help to avert post-operative joint stiffness.[17] In addition, distraction eliminates the weight bearing forces across the subtalar

Figure 8B. CT scan demonstrates the position of the displaced fragment with involvement of the subtalar joint.

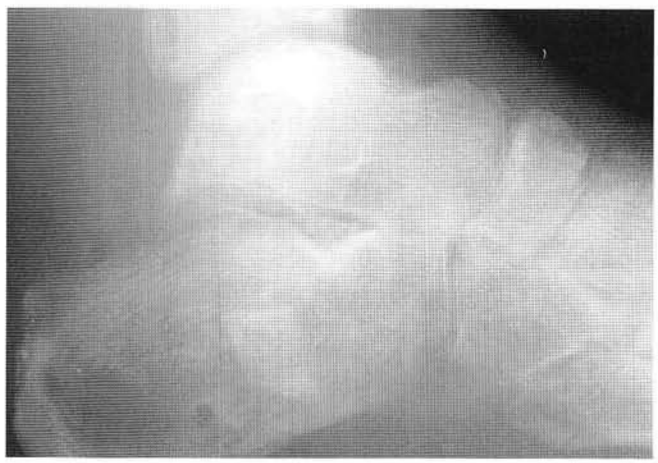


Figure 8D. Post-treatment lateral radiograph following frame removal.

joint, which helps to prevent disruption of a reduced posterior facet. Consequently, cartilage repair and regeneration may be stimulated at the posterior facet articulation, thus delaying the onset of subtalar joint arthrosis.[17]

The method of using external ring fixation in the treatment of calcaneal fractures applies the basic principles and techniques of closed fracture reduction and stabilization through the use of tensioned wires attached to the frame.[18] The goals of the procedure are fracture reduction to restore length, width and height of the calcaneus, minimally invasive open reduction to restore the articular anatomy of the posterior facet, subtalar joint

Figure 9A. Pre-operative lateral radiograph of a 48-year-old male, who jumped into a empty swimming pool and suffered this intraarticular fracture of his calcaneus.

Figure 9C. Post-treatment lateral radiograph demonstrating an anatomically restored posterior facet.

distraction and early weight bearing. This technique has proven to be safe and can be applied in nearly every instance that surgery is indicated including severely comminuted calcaneal fractures, open fractures and situations where soft tissue disruption is so severe that open reduction and internal fixation is contraindicated.

By achieving the goals of restoration of the calcaneal length, width, height and subtalar joint distraction as well as the advantage of immediate postoperative weight bearing, this procedure is a viable alternative for the treatment of all intraarticular fractures of the calcaneus.

Figure 9B. CT scan reveals the extent of the intraarticular fracture pattern.

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