CHAPTER **38**

Calcaneal Fracture Management Via a Combination of Approaches: Double External Fixation Distraction With Minimally-Invasive and Percutaneous Repair

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Management of intra-articular calcaneal fractures is complex, challenging, and evolving. Historically, these injuries have fared poorly with or without surgical intervention (1). Recent advancements and operative technique refinements now offer more promising operative outcomes. Still, there is not consensus on one standard treatment. Instead, many factors must be weighed when determining the most appropriate treatment for a patient.

CONSERVATIVE TREATMENT

Generally, patients with less than 2-mm of subtalar joint (STJ) posterior facet articular surface incongruence are treated conservatively. Greater articular surface incongruence is associated with a worse outcome such as post-traumatic STJ arthritis, higher rates of fracture non-union, deformity, disability, and pain. Regardless of STJ articular surface incongruence, "sick patients" are best-managed with conservative treatment. Anesthesia risks are too great in patients who are not medically stable. Surgery is also avoided in patients likely to have wound-healing complications such as those with uncontrolled diabetes mellitus, those with vascular disease, and smokers. Incision dehiscence and infection can result in calcaneal osteomyelitis, the need for fixation removal, long-term antibiotics, below-knee amputation, prosthesis, and increased costs. Patients who are unable or unwilling to be compliant with nonweight-bearing orders should also be considered for a less complicated, nonsurgical course. Ultimately, patients with failed conservative treatment may require STJ arthrodesis or brace immobilization.

SURGICAL MANAGEMENT

Primary STJ arthrodesis is reserved for the most severe, comminuted intra-articular calcaneal fractures. Otherwise, surgery aims to preserve STJ motion and calcaneal shape. Specific goals of surgery are restoration of the STJ articular surface, neutralization of the heel tuber, and restoration of calcaneal length and width. Restoration of the posterior facet and Bohler's angle decreases the incidence of painful post-traumatic arthritis. Varus heel position must be neutralized to maintain normal STJ motion and function through heel strike. Otherwise, pathologic compensatory changes such as valgus stress of the ankle and midfoot pronation can develop.

Adjunct procedures may be indicated to manage other presenting pathology, such as compartment syndrome, sural nerve impingement secondary to heel widening and lateral wall blowout, anterior calcaneal process fracture, calcaneal-cuboid joint incongruence, and peroneal tendon subluxation secondary to superior peroneal retinaculum insufficiency.

Tuber Reduction

Regardless of the approach utilized, the impacted and varus-malpositioned calcaneal tuberosity fragment must be "pulled out" before the depressed posterior facet segment can be reduced. This can be the most technically-challenging part of the procedure. Various methods have been described to do this (2). The most common technique involves applying distal traction to the calcaneal tuberosity via a lateral-to-medial inserted Shanz pin. A posterior-to-anterior pin could be used alternatively. As the impacted tuberosity is pulled out, the pin is leveraged to neutralize heel varus. Once fluoroscopy assessment confirms acceptable tuber restoration, one holds correction while an assistant provisionally pins the tuber to the constant sustentaculum fragment. Attention is then directed to restoration of the posterior facet articulation – bringing the depressed segment(s) up to match the constant sustentaculum fragment. This can be accomplished through a variety of approaches.

Lateral "L" Extensile Incision Approach

Historically, intra-articular calcaneal fractures have been managed via the lateral extensile incision approach or percutaneous approaches. The small, minimally-invasive sinus tarsi incisional approach has more recently become popular. Each approach has advantages and disadvantages.

The lateral "L" extensile incision approach maximizes visualization and working space for reduction and stabilization of STJ posterior facet articular fracture segments. This approach allows access for perimeter plate reduction and neutralization of forces away from comminuted fractures, with lateral wall blowout, bone loss, and impaction. The main disadvantage of this approach is the high risk for healing complications, with rates ranging from 14-33% (3,4).

Surgery must be delayed until edema is managed and the soft tissue envelope is suitable. Intraoperative considerations include incision placement that respects dermal angiosomes, incision curvature, tissue handling, and closure techniques. "No touch" technique is routine to reduce flap necrosis. Postoperative negative-pressure wound vacuum therapy has also been suggested. Despite these considerations, the lateral "L" extensile incision remains most prone to healing complications.

Percutaneous Approaches

Percutaneous approaches minimize the risk of wound-healing complications. For at-risk patients, this is a major advantage. Unfortunately, percutaneous anatomic reduction of the posterior facet is challenging and at times improbable. Depending on the fracture pattern, timing of surgery, and surgeon experience, it may be possible to percutaneously reduce and stabilize the depressed posterior facet. This is done with pulling, pushing, or prying maneuvers under direct fluoroscopic and/or arthroscopic guidance. Usually, through a small plantar incision, a blunt instrument is inserted in the primary fracture line to elevate the depressed posterior facet. Percutaneously-inserted pins and/or screws then maintain reduction.

Alternatively, the goal of a percutaneous approach may be solely to neutralize the heel and restore calcaneal length and width. If a later STJ arthrodesis is performed, the difficulty of ossifying a wedged interpositional bone graft in the STJ would be avoided. This staged management also provides time to manage smoking cessation, diabetes control, and medically optimize a patient to undergo a longer, definitive arthrodesis operation.

External fixation constructs can be utilized to reduce and maintain calcaneal position and shape. The external fixation approach is the best approach in managing large, open calcaneal fractures. Some routinely use external fixation on closed injuries as well.

Minimally-Invasive, Sinus Tarsi Incisional Approach

A small, linear incision over the sinus tarsi allows access to the posterior facet surfaces. This exposure is not as great as the lateral "L" extensile incision, but fracture segments can still be manipulated and fixation can be placed through this approach. Minimally-invasive, anatomic plating options are available specifically for this incision. Once the lateral wall is freed, the plate can be slid into the desired position. Targeting guides connect to the exposed plate, and orient drilling and insertion of percutaneously-inserted screws into the plate construct (inserted from outside of the sinus tarsi incision).

The sinus tarsi approach has gained popularity. The small incision allows for better exposure than percutaneous methods, allowing for better STJ posterior facet articular reduction. Meanwhile, it is also associated with fewer wound-healing complications than the lateral extensile approach. Extension of the sinus tarsi incision in a proximal or distal direction allows access to the peroneal tendons or the calcaneal-cuboid joint, when needed.

COMBINED APPROACH (MINIMALLY-INVASIVE, PERCUTANEOUS EXTERNAL FIXATION)

The remainder of this article will review a combination of these approaches. Double external fixation is provisionally placed to distract and reduce the heel tuber. A minimally-invasive sinus tarsi incision allows exposure for posterior facet anatomic reduction and fixation. Percutaneous fixation is then added to stabilize the construct. This technique was originally published by Frohlick, in 1999, in German (5). Rodemund and Mattiassich, in Austria, have been using this technique for nearly a decade. They have adapted and continue to optimize the approach. I credit them for sharing their experience and modifications (C. Rodemund and G. Mattiassich; personal communication). Variations of this combined approach have also been described (6).

Operative Technique

The patient is placed on the operating table in the lateral decubitus position (Figure 1). The ipsilateral knee is bent 90 degrees and the foot hangs off the table. An arm or

Figure 1. Lateral decubitus position with the operative leg bent 90 degrees at the knee to overhang the foot off the operative table. An extremity holder is clamped to the side rail of the table to hold this position.

leg holder, clamped to the side rail of the table is used to maintain this leg/foot position. A thigh tourniquet can be used if desired; a calf tourniquet would interfere with the leg holder. Once the patient is secured, the leg is prepped and draped.

The C-arm fluoroscopy unit is draped and positioned at the end of the operative table, facing the table. At the start of the procedure, it is wheeled forward and centered, perpendicular to the rearfoot. The unit's wheels are then locked in place for the remainder of the procedure. This allows the radiology technician to easily "rock the C" at different degrees to obtain a lateral foot projection, a modified Broden's projection, and a calcaneal axial projection (without moving the unit in and out or tilting the C-arm) (Figure 2). This reduces operative time and keeps orientation and fluoroscopy shots consistent. Later, working through the sinus tarsi incision, the C-arm can be rotated to the calcaneal axial projection position where it does not hinder the surgeon's ability to work.

Initially, a lateral rearfoot projection is obtained. A pin is inserted percutaneously from lateral-to-medial through the talar neck. It is important that the pin is perpendicular to the long axis of the talus. Next, a calcaneal axial view is obtained to view the orientation of the heel tuber. A pin is inserted percutaneously through the posterior inferior calcaneal tuber, perpendicular to the tuber (Figure 3). Since the heel is impacted in a varus position, the two pins will not parallel one another. The pins exit closer medially and are further away laterally.

The next step is to apply two distractors and dial out the heel tuber (Figure 4). Uniplanar distractors can be used even though the pins are not parallel. A distractor is first placed over the lateral pins. The pins are bent or the distractor is locked to the pins. Then, distraction is applied until the two pins become nearly parallel. At this time, the medial distractor can more easily be applied over the medial pins. The calcaneal axial view is obtained to allow for assessment of tuber alignment. The medial and lateral devices are now dialed out to ideal position – restoring length of the impacted segment and achieving correction in the frontal plane. This distraction concept is shown in Figure 5.

Many distractors are available. The device should have large enough span to engage the pins and then distract them further. In my experience, 2.4-mm diameter pins work well. Larger pins can be used if your distractor accepts them. Bending and breakage of the pins is minimized by using

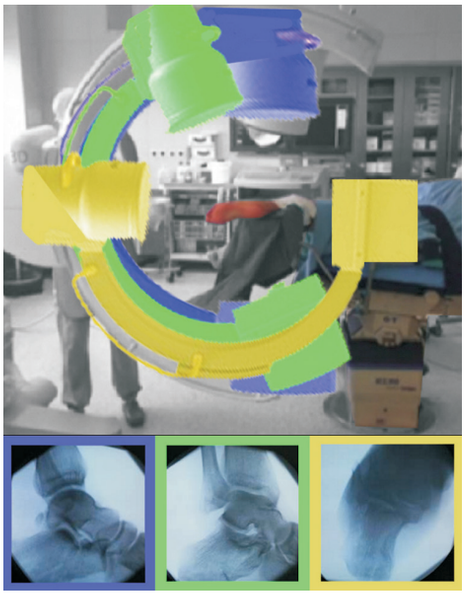

Figure 2. C-arm unit position and arm rotation to achieve views. The unit approaches the foot from the end of the table, perpendicular to the foot. Wheels are locked in place for the duration of the procedure. The C is rotated to obtain the desired view. The beam is oriented perpendicular to the foot for the lateral projection. The C is rotated 10-40 degrees to visualize the posterior facet – this modified Broden's view is useful in assessing anatomic reduction of the posterior facet. A calcaneal axial view is obtained by rotating the C 90 degrees and dorsiflexing the forefoot (using the blue loop of a lap gauze so as to not irradiate the surgeon, as shown in Figure 4) – this is useful in assessing tuber alignment and fixation placement.

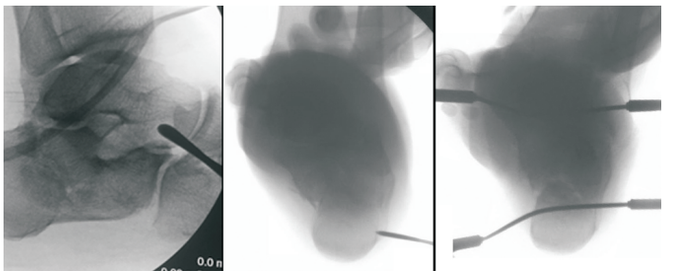

Figure 3. One pin is inserted perpendicular to the talar neck; location identified on lateral projection **(left)**. Another pin is inserted perpendicular to the calcaneus tuber **(middle)**. Medial and lateral distraction allows for restoration of length and neutralization of the tuber **(right)**.

Figure 4. Distractors are placed medial and laterally to dial out tuber reduction. Notice, when the C-arm has been rotated to the calcaneal axial position, and the unit does not hinder the surgeon's access to the foot.

large diameter pins and by connecting the distractor onto the pins as close as possible to the skin surface. Inserting a pin in the posterior inferior calcaneal tuber does not later interfere with screw placement. Once optimal tuber position is achieved, the distractors are locked.

A sinus tarsi incision is then created. Length can vary depending on the need for exposure of the peroneal tendons or access to the calcaneal cuboid joint. The sural nerve and peroneal tendons are retracted. The lateral talar process and subtalar joint are easily identified. The calcaneus lateral wall can be manipulated or temporarily removed to allow for access and visualization, as necessary. Any fracture hematoma is removed and posterior facet fracture segments are reduced. Temporary pin fixation is inserted and extends from the lateral and into the sustentaculum fragment medially. Anatomic posterior facet congruence is directly visualized and confirmed via Broden's and lateral foot projections. Orientation of the pin is assessed with the lateral and calcaneal axial projections. One or two fully-threaded, cannulated screws (2.7- to 4.0-mm diameter options) are then placed to maintain correction of the facet (Figure 6). Through this minimally-invasive approach, bone graft can also be placed to support the facet if desired. The incision is then closed in layers.

Last, a 1 cm long, longitudinal incision is made to the posterior heel, superior to the calcaneal pin. Dissection is

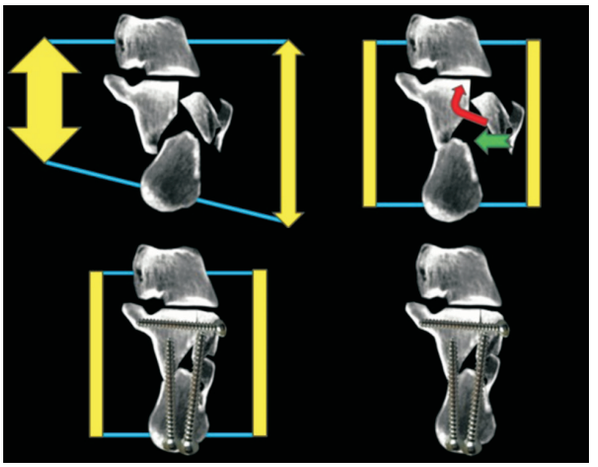

Figure 5. Dual distraction diagram. Pins inserted perpendicular to the talus and calcaneus. Distraction restores length and neutralizes heel varus.

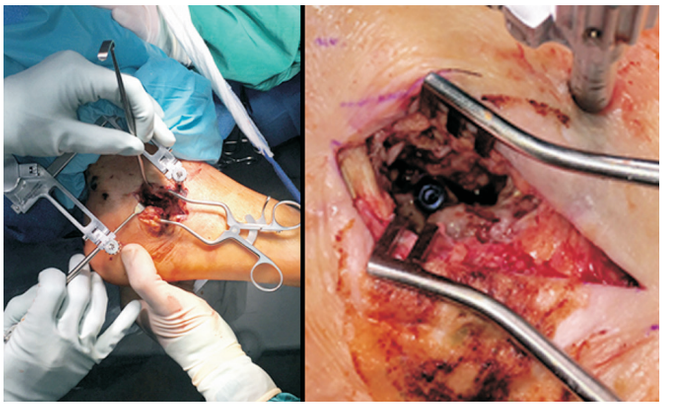

Figure 6. Minimally-invasive sinus tarsi approach. Fracture access, reduction and fixation can be performed through this incision. The incision can be lengthened to expose the peroneal tendons and calcaneal cuboid joint if necessary.

Figure 7. Case 1. Clinical view, fracture blisters were first managed.

Figure 8. Case 1. Preoperative imaging of intra-articular calcaneal fracture with posterior facet depression; Sanders Type IIA.

carried down to bone. Two diverging pins are inserted, so as to stabilize the tuberosity to the sustentaculum and anterior segments. Pin position is assessed under fluoroscopy and fully-threaded cannulated screws are inserted over the pins. Headless or countersunk, headed screws can be inserted (6.5-7.3-mm diameter options).

All pins and the medial and lateral distractors are removed. The patient is placed in a Jones compression dressing and posterior splint, and remains nonweight-bearing. Sutures are removed after 2 weeks and range of motion exercises are started at 4-6 weeks. Partial weight-bearing begins at 6 weeks or when radiographically ready.

CASE REPORTS

Case 1.

A 64-year-old man fell 12 feet off a ladder. He presented with an intra-articular, STJ depression calcaneal fracture and associated fracture blisters (Figure 7). Due to the severity and location of the blisters, these were first managed. He was instructed to quit smoking (previously smoked 1 pack per day). The patient was taken to surgery 2 weeks after injury. The combined approach was utilized. The postoperative view depicting the sinus tarsi incision is shown in Figure 4. Preoperative and intraoperative images are shown in Figures 8 and 9. The patient healed well clinically and radiographically without complication (Figure 10).

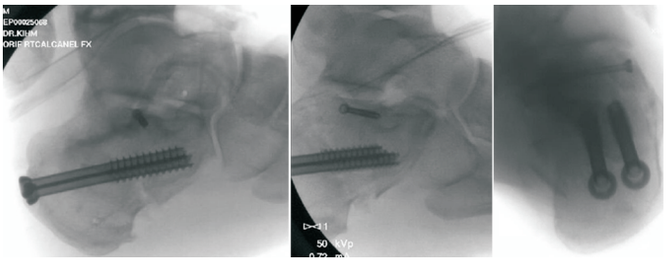

Figure 9. Case 1. Intraoperative lateral projection demonstrates restoration of heel height and length. Broden's view shows reduction of the posterior facet surface. Calcaneal axial view shows neutralization of the heel tuber.

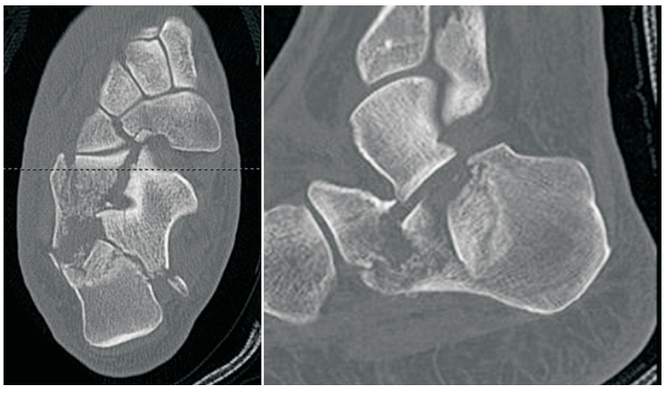

Figure 11. Case 2. Preoperative computed tomography image of intra-articular calcaneal fracture with posterior facet depression.

Case 2.

A 37-year-old man fell 17 feet off a ladder. He presented with an intra-articular calcaneal fracture. The patient had a history of methamphetamine abuse. The combined approach was performed. Preoperative and postoperative images are shown in Figures 11 and 12. The patient healed well without complication.

DISCUSSION

There is not a consensus of the best treatment for intra-articular calcaneal fracture injuries. Most recent literature supports surgical intervention for healthy patients with fracture displacement. Basile reported better functional outcomes for surgical patients; AOFAS score of 86.22 versus 70.26 for conservatively-treated patients (7). Pain outcomes were also better for surgical patients; with a score of 21.0 on a visual analog scale (VAS) versus 44.06 for conservatively-treated patients.

Precision of posterior facet reduction and Bohler's angle re-establishment are key for successful surgical outcome. Anatomic reduction patients have long-term AOFAS scores of 90.6 and VAS 14.38. Whereas, "nearly-anatomic reduction" patient outcomes are only slightly better than conservative outcomes (AOFAS of 74.8, VAS 38.2) (7). The lateral "L" extensile incision and minimally-invasive sinus tarsi incisions allow best direct visualization and access

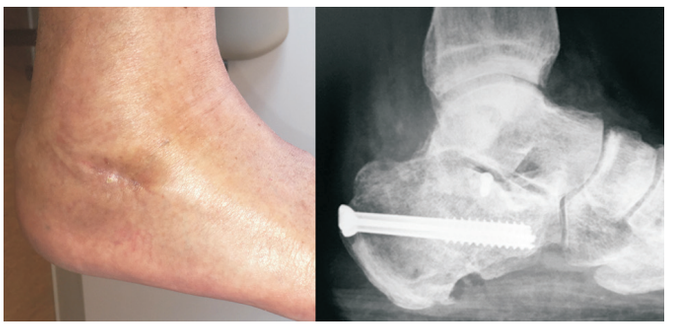

Figure 10. Case 1. Patient went on to consolidate and heal uneventfully. Partial weight-bearing was started at 6 weeks.

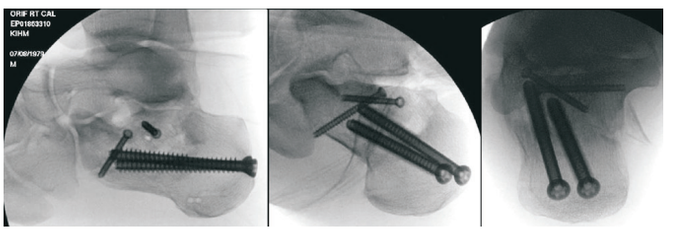

Figure 12. Case 2. Intraoperative lateral, Broden's, and calcaneal axial projections. Posterior facet and Bohler's angle restored.

to the posterior facet. Since the lateral "L" extensile incision is most likely to have healing complications, minimally-invasive techniques are gaining popularity.

A 2016 meta-analysis compared outcome results of minimally-invasive surgical techniques (sinus tarsi incision, percutaneous reduction and fixation, and external fixation approaches) (8). It was concluded that the minimally-invasive sinus tarsi approach and percutaneous reduction and fixation techniques yield similar and superior outcomes than external fixation techniques, with higher AOFAS scores, superior correction of Bohler's angle, and lower infection rates.

Each surgical technique has its own profile of advantages and disadvantages. The combined surgical approach attempts to optimize this profile by allowing access for anatomic reduction and fixation while minimizing wound-healing complications. The combined approach, as described here, has many benefits. This technique can be performed immediately or within days or weeks of injury. In most cases, surgery must not be delayed for weeks, as is typically the case when using the lateral extensile approach. One study reported that surgical intervention was delayed an average of 12.4 days longer when using the extensile approach (7 days after injury for sinus tarsi approach compared to 19.4 days after injury for the extensile approach) (9). This has several implications. Less delay to intervention means the patient will ultimately heal and return to function sooner. Less delay also means that the fracture fragments should be easier to reduce. When surgery is delayed for weeks, the fracture can "get sticky," making reduction more challenging. For these reasons, it is recommended that minimally-invasive procedures are done within 1 week of injury, when possible. Minimally-invasive surgery delayed over 2 weeks is also associated with higher wound-healing complication rates (10). The sinus tarsi access allows for insertion of an elevator to free the lateral wall and pry apart the segments, if needed when intervention is delayed.

The minimally-invasive sinus tarsi incision has several additional advantages over the lateral "L" extensile incision. While both provide exposure for posterior facet fracture reduction and fixation, the sinus tarsi approach is not plagued with high wound-healing complication rates (3-11). If there would be a healing complication, the size of the wound would likely be smaller and more manageable. The smaller approach requires less dissection and can be closed faster, resulting in relatively shorter operative times. Weber reported that the sinus tarsi approach offers a shorter duration of surgery by 52 minutes (11).

In my experience, the double distraction technique provides easier, faster, and more precise tuber reduction than Schanz pin traction. The double distraction technique can be performed with one surgeon, whereas, Schanz pin manipulation requires one person to reduce the tuber and one person to simultaneously fix the tuber to the sustentaculum. If the tuber is not reduced, anatomic reduction of the posterior facet may not be possible; magnifying the importance of tuber reduction. Tuber reduction through distraction and arthrodiastasis requires pin insertion perpendicular to the talus and calcaneal tuber. This operative technique works well with the fluoroscopy approach, as described, to provide consistent projections and save time (C. Rodemund and G. Mattiassich; personal communication).

The choice for fixation is determined primarily by fracture pattern and patient factors. Minimally-invasive techniques allow for plating but many fractures can adequately be stabilized with a few screws, as described. Most reports on percutaneous approaches have been used to treat Sanders II and III injuries, although, Sanders IV injuries have also been reported. A lateral neutralization plate and a handful-of-screws construct is not required for all calcaneal fractures. Less fixation should be considered when suitable as it is less invasive and less expensive. Furthermore, in the event of painful hardware, exposed hardware, osteomyelitis, need for STJ arthrodesis, etc., it will be easier, quicker and less invasive to percutaneously remove 3-4 screws than to again create a large lateral "L" extensile incision to remove a neutralization plate and screws.

There is a need for more outcome studies on this and similar techniques. Frohlich, who originally described this technique, reported on 34 patients. Of these, 80% were described to have excellent or good results and a low 2.1% wound-healing complication rate was reported (5). A larger outcome study by Mattiassich et al of 182 cases utilizing this technique reported low rates of wound complication (2.7%) and long-term need for secondary subtalar joint arthrodesis (4.7%) (12). Dayton described a modified technique but did not report patient outcomes (6). His technique differs in that medial and lateral external fixators are maintained throughout the recovery, instead of inserting posterior to anterior screws and removing the distractors. Dayton suggested that continued distraction and STJ arthrodiastasis offers protection of the cartilaginous surfaces and maintains ankle mobility (6). Further outcome-based studies are needed to compare and optimize the procedure.

In conclusion, evolving surgical techniques provide a more optimistic outcome for intra-articular calcaneal fracture patients. In my experience, the double distraction technique allows a single surgeon to obtain neutral tuber alignment, which is otherwise difficult. Using a small sinus tarsi incision and screw fixation, is often adequate and offers numerous advantages over the traditional lateral "L" extensile approach. The described combination approach has been effective in my experience but additional long-term study focused on outcome is needed.

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