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Short-Term Radiographic Outcomes of Calcaneus Fractures Treated With 2-Incision, Minimally Invasive Approach

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Abstract

Background: The treatment of displaced, intra-articular calcaneus fractures is controversial. The extensile lateral approach has been historically preferred because it provides excellent exposure and visualization for fracture reduction. However, soft tissue complications with this approach can lead to poor outcomes for patients. Recently, there has been an interest in the minimally invasive treatment of calcaneus fractures. The purpose of the present study was to determine the radiographic reduction of displaced, intra-articular calcaneus fractures and the rate of complications using a 2-incision, minimally invasive approach.

Methods: A dual-incision, minimally invasive approach with plate and screw fixation was utilized for the treatment of 32 patients with displaced, intra-articular calcaneus fractures. Preoperative and postoperative calcaneal measurements were taken to assess fracture reduction. Additionally, a retrospective chart review was performed to assess for complications.

Results: The mean preoperative Bohler's angle measurement was 12.9 (range, –5 to 36) degrees and the final postoperative Bohler's angle was 31.7 (range, 16-40) degrees. One patient (3.1%) had postoperative numbness related to the medial incision in the calcaneal branch sensory nerve distribution. Two patients (6.2%) had a wound infection treated with local wound care and oral antibiotics, while 1 patient (3.1%) had a deep infection that required a secondary surgery for irrigation and debridement. Two patients (6.2%) returned to the operating room for removal of symptomatic hardware.

Conclusion: Operative fixation of displaced, intra-articular calcaneus fractures treated with a 2-incision, minimally invasive approach resulted in acceptable fracture reduction with a minimal rate of complications.

Level of Evidence: Level IV, retrospective case series.

Keywords: calcaneus, fracture, intra-articular, minimally invasive, two-incision

Introduction

Calcaneal fractures account for approximately 60% of traumatic tarsal bone injuries and 1% to 2% of all fractures.[2,4,6,7,11,15,19,28] The treatment of displaced, intra-articular calcaneus fractures is controversial, in terms of deciding operative versus nonoperative treatment and the best surgical approach for operative cases.[37] The extensile lateral approach has historically been preferred[6,21,29,36,38] because it provides excellent exposure and visualization of the fracture, allowing for direct fracture reduction and stable fixation.[29] However, soft tissue complications can be high with this approach, which can result in poor outcomes, which are more frequent with open fractures and comorbidities such as smoking and diabetes.[12,26] Postoperative wounds with the extensile lateral approach occur in up to 27% of cases, with superficial infection rates as high as 10.7% and deep infection rates of 5.6% reported. Deep bone infection or osteomyelitis rates of 2.5% have been reported.[3,4,16,17,21,31,35,37] The resulting medical costs and patient morbidity related to infectious complications in the treatment of calcaneal fractures is considered prohibitive by some.[5]

These complicating factors have fostered interest in the development of minimally invasive approaches. Such approaches have been described in the literature, including the McReynolds-Burdeaux (medial) approach,

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the Essex-Lopresti (percutaneous) maneuver, and the Palmer lateral, limited lateral, sinus tarsi, combined medial and lateral, posterior, and various other percutaneous approaches.[1,8-10,12,14,18,22-24,30,40,43,44] However, the radiographic and clinical outcomes associated with these minimally invasive alternative approaches continue to be explored.[3,4,8,12,13,20,21,27,32,34,35,38,39,41] The soft tissue benefits of these approaches are countered by concerns of inferior fracture reduction. Additional benefit from minimally invasive approaches may include shorter operative time.[42]

At our institution, a combined lateral sinus tarsi and medial approach as described by Carr[12] is frequently utilized to minimize soft tissue trauma. This combined approach allows for appropriate exposure and access for fracture fixation with less soft tissue trauma. The aim of the current study was to assess the radiographic results and complication rates when using a 2-incision, minimally invasive approach for the treatment of displaced, intra-articular calcaneus fractures.[12] We hypothesized that this approach would allow for the restoration of key radiographic calcaneal measurements while reducing soft tissue complications compared with results for the extensile lateral or other minimally invasive techniques.

Methods

Medical records of patients surgically treated for isolated calcaneus fractures from 2007 to 2015 were reviewed. Inclusion criteria were intra-articular displaced calcaneal fracture, surgery performed by a single foot and ankle fellowship-trained orthopedic surgeon, a medial and sinus tarsi approach, and at least 10 weeks of follow-up to be consistent with other published studies.[22] Other criteria included documented wound healing, preoperative and postoperative radiographs, and preoperative computed tomography (CT) scans of the affected extremity. Exclusion criteria included extra-articular calcaneus fractures, additional fractures of the ipsilateral foot, follow-up of less than 10 weeks, and surgical technique other than the minimally invasive 2-incision approach. The principal outcome measures were restoration of angular and linear calcaneal dimensions and rate of postoperative wound complications. Other outcome measures were rates of nonunion and secondary surgeries, and any other postoperative complications. Additional data collected included patient age, gender, mechanism of injury, injured extremity, time to surgery from date of injury, smoking history, diabetes, presence of fracture blisters, and time to follow-up.

We identified 32 patients that met the inclusion criteria. Twenty-six (81.2%) patients were male, the average age was 47.2 (range, 22-79) years, and 23 (71.9%) fractures were on the right side (Table 1). One (3.1%) fracture was open. Injury mechanisms showed 20 (62.5%) fractures due to a fall from height, 7 (21.9%) due to a jump from height, 2 (6.2%) from a motor vehicle collision, and 1 (3.1%) each related to hang gliding, skydiving, and rodeo. Ten (31.3%) patients smoked at the time of injury, none (0%) had diabetes, and 3 (9.4%) had fracture blisters. The average time from injury to surgery was 7.8 (range, 0-19) days unless fracture blisters were present, causing a delay of 12 (range, 11-14) days. The average follow-up period for all patients was 35.3 (range, 10-212) weeks.

Table 1. Demographic Data.

Characteristic	Value
Gender	26 male/6 female (81.3% male)
Age, y (range)	47.2 (22-79)
Side of injury	23 right/9 left (71.9% right)
Mechanism	20 fall from height 7 jump from height 2 motor vehicle collision 1 hang gliding 1 skydiving 1 rodeo
Time from injury to surgery, d (range)	7.8 (0-19)
Smoking	10 (31.3%)
Diabetes	0
Fracture blisters	3 (9.4%)
Sanders classification	16 Sanders IIA (50%) 9 Sanders IIB (28.1%) 2 Sanders IIIAB (6.2%) 4 Sanders IIIAC (12.5%) 1 Sanders IV (3.1%)
Follow-up, d(range)	246.9 (67-1490)

Preoperative CT scans were reviewed to assess Sanders fracture classification[29] and to conduct pre- and postoperative calcaneus measurements. Sanders classification was determined based on the number of articular fracture lines seen on the coronal image at the widest point of the posterior facet of the calcaneus. A fracture line was recorded if it was displaced by greater than 2 mm.[2] Based on the Sanders classification system for calcaneus fractures,[29] included in the study were 16 type IIA, 9 type IIB, 2 type IIIAB, 4 type IIIAC, and 1 type IV. There were no primary subtalar fusions performed during the initial surgery in this study group.

Radiographic measurements included pre- and postoperative Bohler's angle, angle of Gissane, calcaneal height, and calcaneal length.[2,22] All measurements were from the lateral radiograph and are consistent with other published studies evaluating calcaneal fractures.[9,34] Bohler's angle was measured as the angle formed by the intersection of a line drawn from the superior point of the anterior process to the superior point of the posterior facet and a tangential line drawn from the superior point of the posterior facet to the

Figure 1. Sinus tarsi incision.

superior edge of the calcaneal tuberosity. The angle of Gissane was measured as the angle formed by the intersection of a line drawn from the anterior downward slope of the posterior facet to the upward slope of the anterior process. Calcaneal height was measured as the orthogonal distance from the inferior cortex of the calcaneus to the superior point of the medial posterior facet.[2] Calcaneal length was measured as the orthogonal distance from the most posterior aspect of the calcaneal tuberosity to the most distal edge of the calcaneocuboid joint.[20]

Statistical analyses of the pre- and postoperative radiographic measurements were performed with a statistical program (SAS 9.3; SAS Institute, Cary, NC). Paired *t* tests were done on measurements of Bohler's angle, the angle of Gissane, calcaneal height, and calcaneal length. Statistical significance was set at $P < .05$.

Operative Technique

The operative technique was performed as described by Neary et al.[25] Patients underwent general anesthesia augmented with regional block. All patients were administered preoperative intravenous antibiotics. The patient was placed in the prone position on a radiolucent table and a thigh tourniquet was used. The sinus tarsi incision was made first from the distal tip of the fibula toward the base of the fourth metatarsal just distal to the calcaneocuboid joint (Figure 1). The incision length averaged approximately 4 to 5 cm. The posterior facet and intra-articular fracture lines were then identified. The depressed posterior facet was then elevated, which was a critical part of the procedure so it would not block the tuberosity reduction later in the case. A Schanz pin was then placed percutaneously through the Achilles tendon into the posterior tuberosity at its superior margin and used as a joystick to manipulate the tuberosity correcting varus and restoring length.

Next, the medial approach was made, as described by Burdeaux.[8,9] The incision was initiated 2 to 3 cm anterior to the posterior tuberosity margin and coursed slightly distal to proximal obliquely. The incision was approximately 3 to 4 cm. Meticulous care was taken to avoid damage to the medial calcaneal sensory branch (Figure 2). Once down to the calcaneus, dissection was performed using a Cobb elevator to elevate soft tissue and intrinsic muscles off the medial aspect of the calcaneus. The medial spike was identified and protected, particularly if there was medial comminution.

By using a push-pull technique, the calcaneal tuberosity was reduced to the superomedial spike, reestablishing calcaneal height and length. Thumb pressure was applied to dorsiflex the medial spike while simultaneously pulling posteriorly and plantar-ward on the Schanz pin. Once the maneuver anatomically reduced the tuberosity, a drill hole was made perpendicular to the tuberosity opposite the apex of the spike on the calcaneal tuberosity side of the fracture. Through use of a small, flexible antiglide plate such as a mini-frag 5-hole quarter tubular plate, the center hole of the plate was applied over the drill hole. A 3.5-mm fully threaded cortical screw was then advanced through the hole. Once it approached contact with the plate, the reduction maneuver described above was performed and the screw was tightened, reducing the tuberosity to the superomedial fragment with the push-pull technique. The reduction of the tuberosity allowed for restoration of calcaneal height, width, and length.

Direct visualization and reduction of the anterior process and posterior facet fracture fragments was now possible in the sinus tarsi wound. Provisional fracture fixation was achieved with K-wires. Fluoroscopy and direct visualization confirmed appropriate fracture reduction. It is not uncommon to have a fracture line through the calcaneus anterior to the posterior facet, allowing relative plantarflexion of the calcaneal tuberosity and posterior facet to the anterior calcaneus. In these cases, reduction was achieved by dorsiflexing the Schanz pin while applying plantar force, followed by plantarflexion of the foot with the surgeon's thumb as the fulcrum point on the plantar foot at the level of the anterior fracture line. Guide pins for large cannulated screws were then run from posterior to anterior as provisional fixation. The preferred screw diameter was 5.5 mm or less to reduce the likelihood of cross-interference between screws. Final posterior facet articular fracture fixation was achieved with 4.0-mm cannulated screws. Based on the fracture pattern, particularly if there was tuberosity comminution, a combination of locking/nonlocking plate with screws or large cannulated posterior-to-anterior fully threaded screws were utilized at the discretion of the surgeon (Figure 3). On preoperative radiographic evaluation, the anterior calcaneus and calcaneocuboid joint were inspected. After anatomic reduction of the posterior facet, reduction of the anterior calcaneus was achieved by keying in the

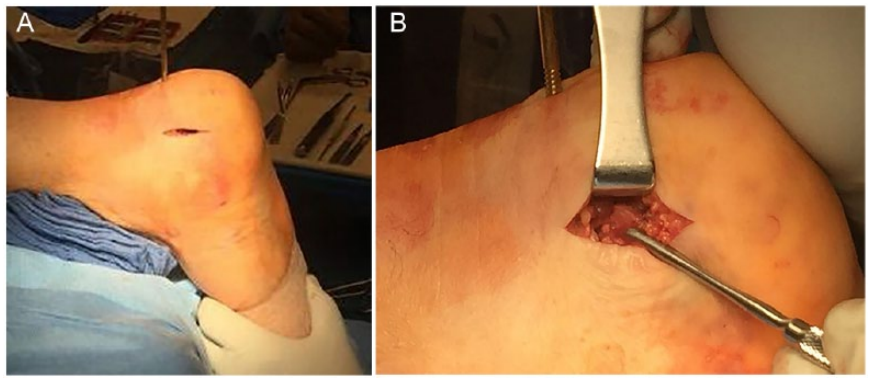

Figure 2. (A) Medial approach. (B) Medial spike seen through the medial approach.

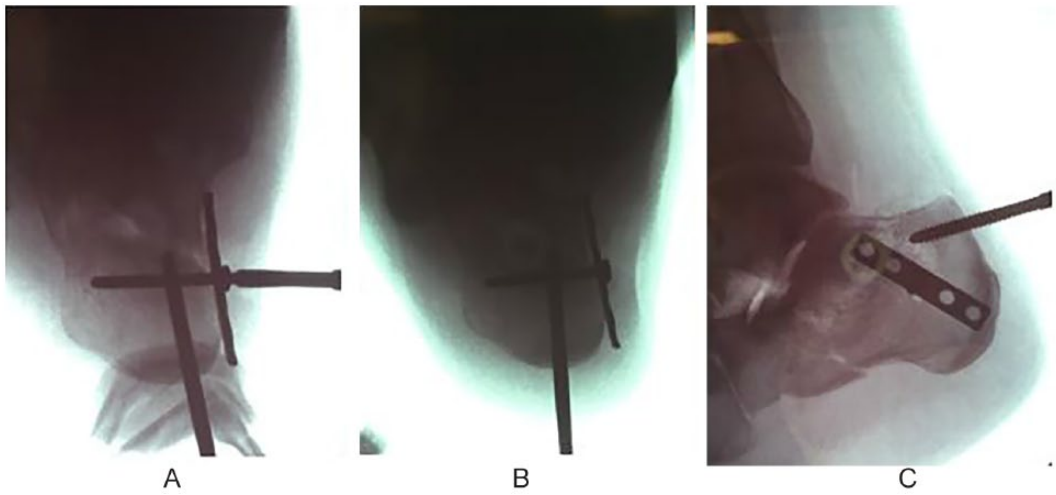

Figure 3. Intraoperative radiographs demonstrating the push-pull technique. (A) The Schanz pin is pulled while the screw is carefully tightened. (B) Once the medial spike keys in anatomically, the tuberosity is reduced with inherent stability out to length and out of varus. (C) The posterior facet can now be reduced and correction of Bohler's angle can be achieved if there is an anterior fracture line to the posterior facet, as seen in this fluoroscopic image.

fragments of the sinus tarsi. Extension of the incision to allow visualization of the calcaneocuboid joint was sometimes necessary. All wounds were irrigated and closed in a layered fashion.

Sterile dressings were applied and patients were placed into a well-padded, short leg splint and made nonweightbearing on the operative extremity. Patients were placed into a walker boot at 2 weeks postoperatively and physical therapy was started. Active range of motion of the ankle and subtalar joints was encouraged during this period. Patients were kept nonweightbearing for 10 weeks, consistent with other published studies,[21,22] pending evidence of radiographic union. Progressive weightbearing in the walker boot was initiated at 10 weeks and patients were allowed to wean from the boot as able.

Results

Radiographic Outcomes

A board-certified orthopedic surgeon completed radiographic assessment. All patients achieved successful union. The preoperative Bohler's angle was 12.9 (range, –5 to 36) degrees and the postoperative angle was 31.7 (range, 16-40) degrees ($P < .001$) (Table 2). The preoperative angle of Gissane was measured as 124.9 (range, 100-146) degrees and the postoperative angle was 123.8 (range, 104-146) degrees ($P > .05$). The preoperative calcaneal height was 45.1 (range, 36-53) mm and the postoperative height as 49.6 (range, 42-58) mm ($P < .001$). The preoperative calcaneal length was 77.3 (range, 60-89) mm and the postoperative length was 78.1 (range, 67-89) mm

Table 2. Radiographic Parameters.

Measurement	Preoperative	Postoperative	*P* Value
Bohler's angle, deg (range)	12.9 (−5 to 36)	31.7 (16-40)	<.001
Angle of Gissane, deg (range)	124.9 (100-146)	123.8 (104-146)	>.05
Calcaneal height, mm (range)	45.1 (36-53)	49.6 (42-58)	<.001
Calcaneal length, mm (range)	77.3 (60-89)	78.1 (67-89)	>.05

Table 3. Complications of Treatment.

Complication	No.
Numbness (calcaneal sensory branch)	1
Superficial wound infection	2
Deep wound infection	1
Subtalar arthritis	1
Symptomatic hardware	2
Symptomatic Haglund deformity	1

($P > .05$). All fractures had less than 1mm of posterior facet joint displacement.

Complications

The complications are summarized in Table 3. One patient (3.1%) had postoperative numbness related to the medial incision in the calcaneal branch sensory nerve distribution. Three (9.4%) patients experienced a wound infection. One (3.1%) patient had a deep infection and required surgery for irrigation and debridement. There were 2 (6.2%) patients with superficial infections requiring only oral antibiotics and local dressing care for resolution. Both superficial infections were related to the medial incision. The deep infection that required surgical irrigation and debridement was of the lateral incision. One (3.1%) patient developed subtalar pain that was treated with subtalar joint steroid injections. Two (6.2%) patients returned to the operating room for removal of symptomatic hardware, one of whom also underwent partial excision of the posterior calcaneus (excision of Haglund deformity). No patients experienced nonunion or malunion, had a loss of reduction, reported complications related to trans-Achilles Schanz pin, or reported flexor hallucis longus irritation from the medial plate.

Discussion

The management of intra-articular calcaneus fractures remains controversial. There are numerous factors that influence a surgeon's decision regarding which approach to use, including fracture pattern, patient comorbidities such as smoking and diabetes, skin condition, and time from injury to presentation. The goal of all approaches is to minimize soft tissue trauma while achieving anatomic fracture reduction and stable fixation. Minimally invasive approaches offer decreased risk of wound complications, though success in achieving the operative goal of anatomic fracture reduction is still under review. Our study reports on the radiographic and clinical results of 32 patients with displaced, intra-articular calcaneus fractures treated with a minimally invasive, 2-incision (medial and sinus tarsi) approach. The 2-incision surgical approach evaluated in the current study demonstrated a statistically significant improvement in Bohler's angle and calcaneal height. Our results are similar to those of other studies reporting radiographic outcomes from minimally invasive approaches of displaced, intra-articular calcaneal fractures. Our study found an average preoperative Bohler's angle of 12.9 degrees and a postoperative angle of 31.7 degrees. Scott et al showed an improvement in Bohler's angle from 7.7 degrees preoperatively to 25.5 degrees postoperatively using a single-incision sinus tarsi approach.[33]

Wound complication rates were consistent with other published studies of minimally invasive approaches and lower compared with published results of the extensile lateral approach. In our study, 6.2% of patients experienced a superficial infection and 3.1% had a deep infection. We had no cases of osteomyelitis. A recent meta-analysis comparing the extensile lateral approach to a sinus tarsi approach found an overall wound complication rate for the extensile lateral approach of 24.9%, with 71% of those classified as minor wound complications and 29% classified as major wound complications.[26] For the sinus tarsi approach, Nosewicz et al report a 4.9% rate of wound healing complications, all classified as minor.[26] Kline et al found a wound complication rate of 6.1% for minimally invasive approaches, none of which required operative intervention, and 29.1% for the extensile lateral approach, 9% of which required operative intervention.[23] In a systematic review of the sinus tarsi approach, Schepers reported a wound complication rate of 0% to 15.4%, with a superficial infection rate of 4.1% and a deep infection rate of 0.7%.[31] Weber et al published a comparison of the extensile lateral approach versus a minimally invasive sinus tarsi approach and reported zero wound complications in the minimally invasive group with only 1 patient (4.2%) reporting a plantar nerve lesion.[42] In our study, there were only 2 secondary surgeries for hardware removal (6.2%) compared with 20%

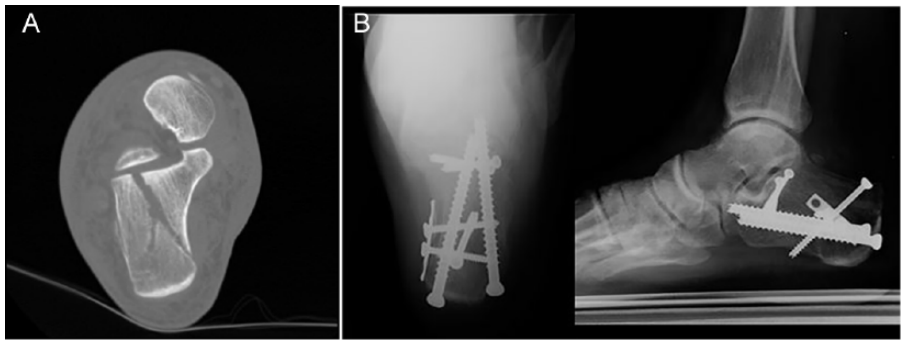

Figure 4. (A) Preoperative axial CT scan. (B) Postoperative Harris heel and lateral view radiograph. Note the anatomic alignment of the medial wall and reduction of the tuberosity out of varus.

with the extensile lateral[34] and only 1 patient (3.1%) developed symptomatic subtalar pain that was treated with steroid injections.

Our study found that a minimally invasive, 2-incision (medial and sinus tarsi) approach was a good option to obtain and maintain fracture reduction while minimizing wound and other complications in the management of displaced, intra-articular calcaneal fractures. The main advantage of the 2-incision technique was the ability to achieve direct, anatomic reduction of the calcaneal tuberosity. In our opinion, this is critical to achieving anatomic reduction of the posterior facet articular surface by removing any incongruencies of the tuberosity that could block reduction of the joint surface. Although there is a risk of nerve injury with the medial approach, only 1 patient in our series had this complication. The small risk of nerve lesion or wound complication was offset by the benefit in using the 2-incision approach, allowing us to achieve anatomic reduction of the tuberosity, which allowed for anatomic restoration of calcaneal height, width, and length.

When planning on using this approach, it is especially important to study the preoperative axial CT images and specifically the medial-sided fracture pattern (Figures 3A and 4A). The push-pull technique through the medial incision is best utilized with minimal medial-sided comminution, in particular at the medial spike, and with only 1 or 2 primary fracture lines. If the medial calcaneal wall is comminuted, it diminishes the inherent stability required for the success of this technique (Figure 5). In addition, when the primary calcaneal fracture orientation is more coronal than axial, the push-pull technique described has less inherent stability. When the medial spike is intact, calcaneal tuberosity anatomic reduction can be achieved (Figures 4 and 6).

There are limitations with our study. First, this is a retrospective review and does not exclude the potential for patient selection bias. There was no patient randomization and no control group for comparison. The senior author (G.L.) utilized this approach in all cases if the fracture pattern was suitable to this technique, so it did not include all fracture patterns. Another limitation is the lack of longitudinal clinical and functional outcomes data, such as rate of return to work, visual analog scale (VAS) pain score, and American Orthopaedic Foot & Ankle Society (AOFAS) score. Our average follow-up was 35 weeks, which is adequate to assess for early complications but may not be long enough to capture patients who developed subtalar arthritis or other complications, such as painful hardware needing removal. There were no postoperative CT scans obtained, which would have allowed for improved assessment of the reduction.

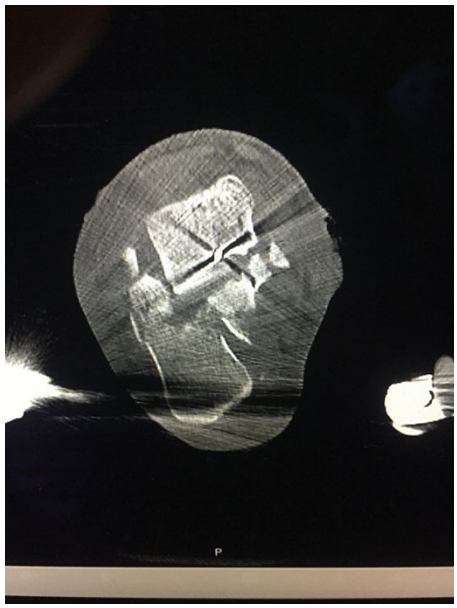

Figure 5. Note the medial comminution, making this fracture less ideal for the 2-incision approach.

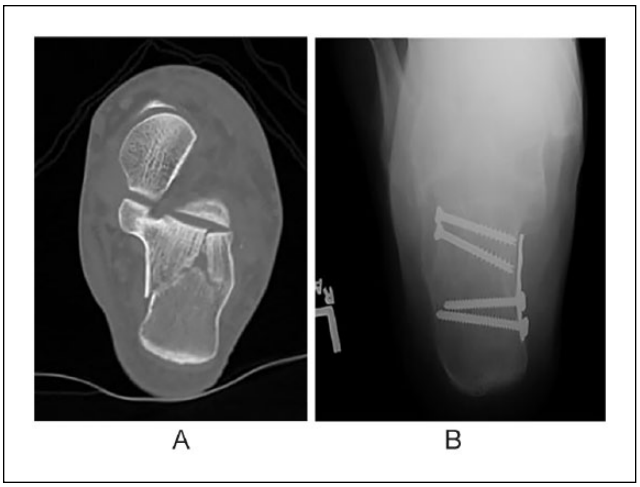

Figure 6. Note on this preoperative axial CT scan image that there is minimal medial comminution, making this fracture pattern ideal for the described approach. (A) The postoperative radiograph is following utilization of the medial approach and push-pull technique, which acts as an antiglide technique along the medial side. (B) This connects the superomedial fragment to the tuberosity, reestablishing calcaneal length and height.

Conclusion

We found that a 2-incision approach was safe and useful to achieve anatomic restoration of displaced, intra-articular calcaneus fractures. Due to predictably good fracture reductions and a low complication rate, this technique has become the preferred method for our practice in treating calcaneus fractures without significantly comminuted medial walls. Larger studies are needed, however, to more effectively compare this approach with the extensile lateral approach and the other minimally invasive approaches.

Declaration of Conflicting Interests

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