A Minimally Invasive, Dual-incision (Medial and Lateral) Approach: An Alternative Technique for Reduction and Fixation of Intra-Articular Calcaneus Fractures

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Abstract: Calcaneus fractures are severe injuries that historically have been associated with poor outcomes and debilitating consequences. To maximize functional outcome, the literature in favor of operative management encourages anatomic reduction and alignment of displaced, intra-articular calcaneus fractures, while minimizing risk to soft tissues. Because of the increased risk of soft tissue complications with extensile approaches, minimally invasive techniques have continued to gain popularity. The current technique aims to describe a minimally invasive approach to calcaneus fractures through a dual-incision, lateral (sinus tarsi) and medial, approach. This approach facilitates anatomic reduction of the calcaneal tubercle to restore calcaneal tuberosity height and length, thus facilitating anatomic reduction of the posterior facet and realignment of the anterior calcaneus while minimizing risk of soft tissue complications. The authors' results support this technique and we recommend it as a safe and effective method for open reduction and internal fixation of displaced, intra-articular calcaneal fractures.

Level of Evidence: Diagnostic Level V. See Instructions for Authors for a complete description of levels of evidence.

Key Words: calcaneus, fracture, medial approach, minimally invasive, surgical technique

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LEARNING OBJECTIVES

After participating in the CME activity, physicians should be better able to:

1. Evaluate calcaneus fracture patterns and identify which patterns are appropriate for medial approach and plating technique.
2. Distinguish the common calcaneus fracture fragments, and employ the described techniques for reduction of these fragments.
3. Assess calcaneus fractures in an organized, stepwise manner, utilizing the medial approach as an adjunct tool for anatomic reduction.

HISTORICAL PERSPECTIVE

Calcaneal fracture treatment strategies date back almost 200 years when it was first described by Malgaigne in 1843.[1] Since then, a long historical record exists detailing various treatment options for these fractures. For many years, calcaneal fractures were managed with closed reduction and immobilization despite poor functional results. Dissatisfied with these outcomes, in the 1920s French surgeon Rene Leriche described a method of open reduction and internal fixation, pioneering surgical efforts for treatment of these injuries.[2] Nevertheless, calcaneus fractures continued to be poorly understood until advances in radiography developed throughout the early 20th century.[1] Yet even though management principles have continued to evolve, they often prove controversial.

As the most commonly fractured tarsal bone, calcaneus fractures account for 1% to 2% of all fractures and 60% of tarsal bone fractures.[1,3] The most common demographic to be affected are young, employed men.[1] These are often high-energy injuries such as falls from height, motor vehicle or motorcycle accidents, or other mechanisms causing a forceful axial load to the hindfoot. Associated injuries often include thoracic or lumbar fractures, chest wall injury, head injury, or other injury to the lower extremities.[3] Less commonly, low-energy mechanisms have also been described. This often involves the elderly population with osteoporosis or other conditions affecting bone density. Regardless of the mechanism of injury, calcaneal fractures are significant injuries that historically have been associated with disabling outcomes.[4,5]

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Controversy regarding treatment of calcaneal fractures exists for both nonoperative and operative management. Currently, the literature remains somewhat divided with respect to the ultimate advantages of surgery. Those in support of operative management argue that treatment with open reduction and internal fixation may restore calcaneal height and length, hindfoot alignment, posterior facet congruency, and overall anatomic structure. As a result, the mechanics of the hindfoot are optimized, and the risk of postoperative pain and dysfunction are minimized.[6,7]

Buckley and colleagues conducted a prospective, multicenter, randomized control trial in which they evaluated 424 patients with 471 displaced, intra-articular calcaneal fractures. Patients were randomized to operative versus nonoperative management with minimum 2-year follow-up. They found that functional results were no better with operative management compared to the nonoperative group, although there was significant improvement in the operative group if workers' compensation patients were excluded.[8] A follow-up study by Barla et al[9] found that in women, operative treatment of calcaneal fractures show statistically significant better results when compared to nonoperative management. Kurozumi and colleagues evaluated functional outcomes of calcaneal fractures following operative management and correlated outcomes with radiographic appearance. Results showed better functional results in patients with lower age, greater Bohler angle at the time of injury, lower Sander grade, less displacement of fracture fragments, and anatomic reduction of the posterior facet and calcaneocuboid joint. They argued these last 2 factors could only be improved with operative management and recommended this treatment course as indicated.[10] Buckley et al[8] found operative treatment to be superior to nonoperative management in patients who were women, had low-demand activities, had minimal deformity, and were not a workers' compensation-related injury. A meta-analysis of the current evidence found that although surgery may increase the risk of complications, operative treatment achieved worthwhile reconstruction results and improved functional outcomes.[11] Radnay and colleagues revealed that for patients who underwent subtalar fusion for posttraumatic arthritis following treatment for calcaneus fracture, those whose fracture was treated operatively had far better outcomes following fusion than those treated nonoperatively. This study stressed the importance of restoring calcaneal shape, height, and alignment at the time of calcaneal fixation to maximize functional outcome.[12]

Studies supporting nonoperative management are based primarily on the complication rates associated with operative treatment. Folk and colleagues evaluated 179 patients with 190 calcaneus fractures, all of whom underwent open reduction and internal fixation. About 25% of the patients developed a wound complication, of which 21% required operative debridement. Risk factors for postoperative wound complications included smoking, diabetes, and open fractures, offering support for nonoperative treatment in patients with multiple risk factors.[13] Griffin and colleagues randomized 151 patients with acute, displaced intra-articular calcaneal fractures into operative versus nonoperative management. Operative treatment showed higher complication rates and no functional advantage 2 years postoperatively, leading to their recommendation for nonoperative management for these fractures.[14]

Despite the controversy regarding functional outcomes following operative versus nonoperative management, there remains a body of evidence in support of surgical management for displaced calcaneus fractures. This body of evidence advocates for operative management to restore calcaneal shape and alignment, optimize hindfoot mechanics, increase functional outcomes, and have a decreased risk of posttraumatic arthritis.[8–12]

Displaced, intra-articular calcaneal fractures have long been operatively accessed through an extensile lateral approach. Unfortunately, this approach has been associated with higher wound and infection complications, likely because of more significant disruption of the vascular supply to the skin resulting in soft tissue necrosis. This has led surgeons to seek out less-invasive approaches. The most common minimally invasive approach described is the sinus tarsi approach, which utilizes a comparatively smaller incision and has a lower risk of wound complications. A recent meta-analysis by Yao et al[15] compared the sinus tarsi and extensile lateral approaches, and reported a markedly lower incidence of wound complications with the sinus tarsi approach, with no significant difference in functional outcomes or restoration of Bohler angle. Nosewicz et al[16] evaluated the reduction and stability of internal fixation using a sinus tarsi approach. Results demonstrated <1 mm step-off in postoperative reduction of the posterior facet, no loss of reduction, and restoration of Bohler angle. Kline and colleagues performed a retrospective review comparing extensile (79) and minimally invasive (33) approaches. The study found no significant difference in clinical results and a significantly lower incidence of soft tissue problems, wound complications, and need for secondary surgeries.[17] Despite these findings and the cited advantages of this approach (among other less-invasive approaches) over the extensile lateral approach, there has been reported concern about the ability of the less-invasive techniques to restore anatomic alignment of the calcaneus and the subtalar joint due to potentially difficult visualization.[18]

In light of the current concerns regarding extensile and less-invasive approaches, the authors of the present study aim to describe an alternative technique to approach open reduction and internal fixation of displaced, intra-articular calcaneal fractures. The technique encompasses a dual medial and lateral sinus tarsi approach to the calcaneus, employing minimally invasive techniques through 2 small incisions. This technique allows anatomic reduction of calcaneal fractures while avoiding the high rates of postoperative wound complications associated with more extensile approaches.

INDICATIONS AND CONTRAINDICATIONS

The ideal fracture pattern for this dual-incision approach is a joint depression Sanders type II/III (A/B/C) with minimal comminution of the medial wall of the tuberosity (Fig. 1A). Mild medial tuberosity comminution does not preclude a medial approach, but reduction of the calcaneal tubercle is dependent on the stability of the medial wall fracture once reduced. Contraindications include significant comminution of the medial tuberosity or medial wall (Fig. 1B), tenuous medial soft tissue that would be at high risk for postoperative wound complications, patients at increased risk for noncompliance to the postoperative plan of care, and medically unstable patients. Medial wall comminution is a contraindication secondary to the fracture pattern not being amenable to the medial push-pull plate.

PREOPERATIVE PLANNING

The goals of open reduction and internal fixation of calcaneus fractures are to anatomically reduce the articular surface(s) and restore normal calcaneal architecture including height, length, and varus/valgus alignment in relation to the contralateral side. The type and quality of preoperative imaging is essential to understand the fracture pattern, fragment displacement, and

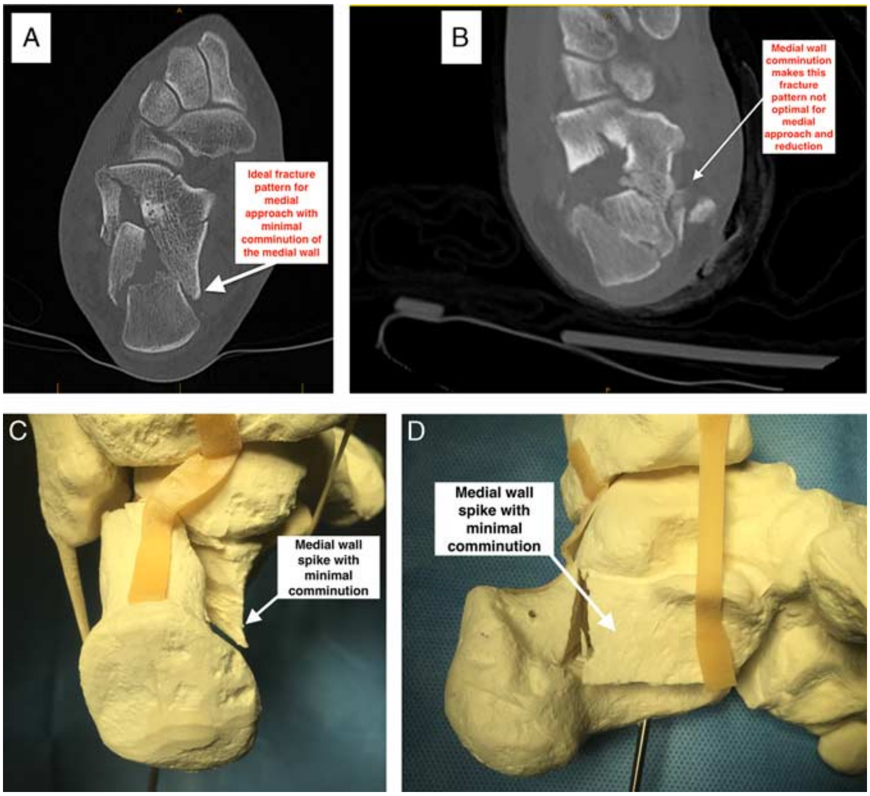

FIGURE 1. Axial CT cuts showing the ideal fracture pattern for a medial approach with minimal comminution of the medial wall (white arrow) (A), and a suboptimal fracture pattern with medial wall comminution (white arrow) that would not be amenable to medial open approach and reduction (B). C and D, Sawbones figures reinforcing ideal fracture pattern (white arrows).

FIGURE 2. Lateral x-ray showing the four main fragments in calcaneal fractures—the depressed posterior facet, the tuberosity fragment, the anteromedial constant fragment (not visualized on lateral x-ray), and a separate anterior calcaneal fragment.

involvement of articular surfaces. Radiographic assessment begins with nonweightbearing anteroposterior (AP) and lateral views of the ankle, and Broden, and Harris views of the calcaneus. Because of the potential of concomitant foot injuries, radiographs should also include nonweightbearing AP, oblique, and lateral (may be included in lateral ankle) views of the foot. A computerized tomography scan of the ankle is also necessary to further evaluate posterior facet fracture pattern and comminution, degree of comminution of the medial wall, varus tuberosity malalignment, and fracture lines extending into the anterior process. It is the authors' recommendation to order a computerized tomography specifically of the ankle versus the foot due to the superiority of beam orientation for interpretation of the calcaneal fracture pattern.

A complete history and physical examination should be performed to specifically identify factors that would determine the operative appropriateness of the patient and the timing of the procedure. Medical optimization by a multidisciplinary team may be necessary. Vascular and neurological assessment should be carefully performed and documented. Soft tissue swelling, fracture blisters, and any wounds including abrasions should be assessed. It is the authors' recommendation to wait until a "wrinkle sign" is present, if possible, and that any fracture blisters are resolved before surgery. Subtalar fracture-dislocations should undergo urgent closed reduction and percutaneous stabilization to expedite assessment of soft tissue appropriateness for more definitive preoperative planning and treatment.

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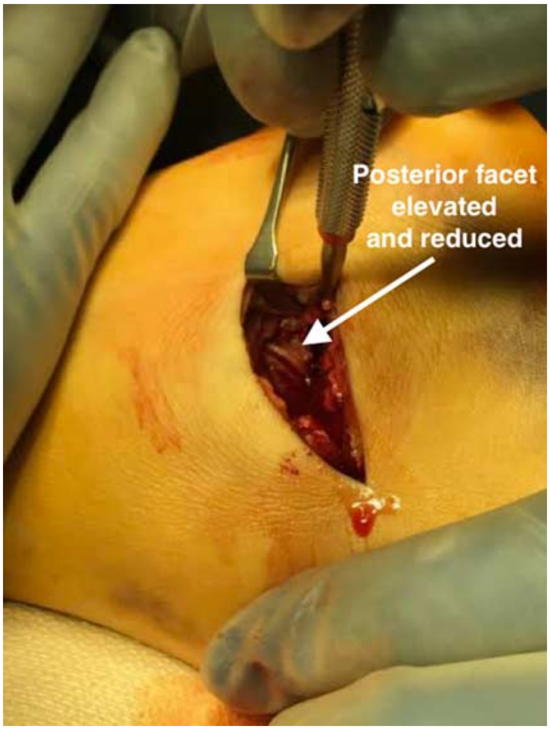

FIGURE 3. Once the fracture line is identified and the impacted posterior facet is mobilized, the posterior facet is elevated and reduced.

SURGICAL TECHNIQUE

The patient is placed in the prone position to allow for easy access to the medial and lateral calcaneus. The affected extremity is elevated on blankets to avoid obstruction by the contralateral leg. The authors categorize displaced calcaneal fractures as having any combination of 4 fragments: the depressed posterior facet, the tuberosity fragment, the anteromedial constant fragment, and a separate anterior calcaneal fragment (Fig. 2). Our approach for reduction and fixation is based on this concept, and repair methodology is generally posterior-to-anterior.

FIGURE 4. Medial approach to calcaneal tuberosity.

The first step is to perform a sinus tarsi incision. Starting at the tip of the fibula, advance and extend the incision anteriorly approximately 3 cm. Take care to identify the peroneal tendons, as they may be dislocated and more anterior. If the peroneal tendons are dislocated, the incision can be curved and the posterior margin extended proximally, allowing sufficient access for repair. The posterior facet is exposed by releasing the talocalcaneal interosseous ligaments and dissecting the blown-out lateral wall fragment free from surrounding tissue. Once the posterior facet is visualized, a freer elevator is used to both identify the fracture line and free up the impacted posterior facet fragment. The posterior facet is then disimpacted and elevated (Fig. 3). This is a critical step, as it elevates the posterior facet and keeps it from interfering with the reduction of the tubercle. Try to avoid levering off the lateral wall while elevating the posterior facet in order to preserve the lateral wall, as it can be an important fragment to aid in the anatomic reduction of the posterior facet. Anatomic reduction is not necessary at this time.

Attention is then turned to reduction of the tuberosity using a medial approach. Starting approximately 2 to 3 cm anterior to the posterior aspect of the tuberosity, make a 3-cm vertical incision with slight proximal-anterior orientation. Take care to center the incision posterior to the contents of the tarsal tunnel, in line with the Achilles tendon (Fig. 4). Following incision, perform dissection with tenotomy scissors down through the subcutaneous tissue. Take care to protect the medial calcaneal branch of the tibial nerve, as it may be visualized in the incision. Continue dissection down to the abductor hallucis, which overlies the medial tuberosity. Use a Cobb elevator or similar instrument to elevate the abductor off the medial wall in a posterior-to-anterior direction. At this point, the medial fracture line should be visible. Fully expose the fracture, and identify both the tuberosity fragment and the constant fragment. If there is comminution, take care to not disrupt the periosteal and/or soft tissue stability of these medial fragments.

Proceed with placement of a Schanz pin in the calcaneal tuberosity to aid in reduction (Fig. 5). When placing the Schanz pin, the surgeon should consider that the tuberosity is usually in varus malalignment with some degree of shortening and loss of height. It is important to evaluate imaging preoperatively, as the fracture pattern will often dictate where the Schanz pin can be placed. Our preferred method is to place the pin within the superior tuberosity, as this contains the densest bone and generally less fracture comminution. Occasionally, the pin must be placed more inferiorly. Place the pin at the midline of the tuberosity, but angled into varus so that when the tuberosity is reduced out of varus back to neutral, the pin will be directly vertical in line with the calcaneus. Once the position of the Schanz pin is determined, make a stab incision and place an approximately 4.5 mm self-drilling/tapping pin; this can be done under fluoroscopy if desired. Make sure the Schanz pin does not cross the main tubercle fracture line. Occasionally, the Schanz pin will pull out during reduction maneuvers. The surgeon can either replace the same pin in a different location or exchange for a larger diameter pin.

Once both fragments are fully visible, proceed with reduction of the tuberosity. The reduction maneuver is often a simultaneous process of plantarflexing the foot, which plantarflexes the constant fragment and relaxes the Achilles tendon, and simultaneously pulling the Schanz pin (and tuberosity) with a posteriorly, inferiorly, and valgus-directed force. The surgeon can assist the reduction by placing a thumb on the inferior

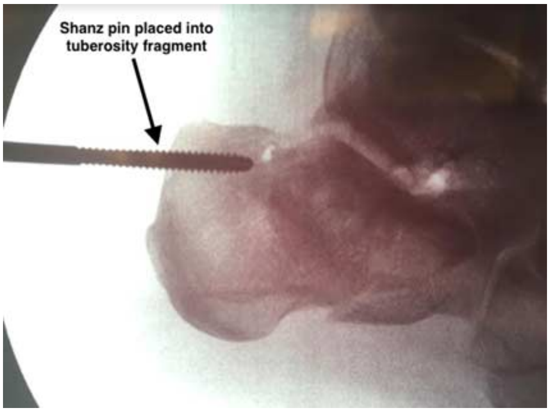

FIGURE 5. A Schanz pin is placed into the tuberosity under fluoroscopic guidance to help aid in tuberosity reduction.

medial spike. By using this maneuver, the heel may be brought out of varus malalignment, while also gaining length and height of the calcaneus. If there is no medial comminution, anatomic reduction of the calcaneal tuberosity can be achieved due to the stability of the medial spike that is often present (Fig. 6). Although this reduction can be relatively stable, augmentation with a k-wire can also be utilized. Once the tuberosity appears to be anatomically reduced to the constant fragment medially, proceed with Harris and lateral views to ensure neutral heel alignment and restoration of calcaneal pitch.

Once adequate reduction has been achieved, proceed with internal fixation of the medial tuberosity. Place a 4-to-6 hole ¼ tubular plate spanning the constant fragment and tuberosity, which acts in an antiglide manner. The flexibility of this plate is preferred over a more rigid plate, as the antiglide and push-pull reduction principals require the plate to conform to the medial wall of the calcaneus. If possible, hold the fracture in a reduced position and make a drill hole for a bicortical 3.5 mm screw in the tuberosity. Take care to place this first drill hole on the tubercle side of the fracture opposite the apex of the medial spike (Fig. 7). Depending on the anatomy, place the ¼ tubular plate so that it spans the fracture at ~45-degree angle to the calcaneus. Ensure there are at least 2 holes on each side of the fracture spike. Two screws in the tubercle fragment are generally preferred for most fracture patterns, as a single screw may not control for rotation (Fig. 8). With the tuberosity and medial wall held reduced, and the plate confirmed to be in proper position, proceed with placing the first predrilled screw through the plate and into the tuberosity. The fracture does not necessarily be anatomic, as the plate will assist in the anatomic reduction once it engages on the medial wall of the calcaneus. While advancing the screw, make sure reduction is being held while the screw is being placed. Perform the reduction maneuver as previously described until the screw and plate are against bone and the tuberosity is reduced (Fig. 9). Obtain a Harris view to ensure the heel has been brought out of varus into neutral alignment, and that the plate is sitting properly along the medial calcaneus. If done correctly, the plate (acting as an antiglide) will hold the tuberosity in neutral alignment, reduced to the constant fragment (Fig. 9). Obtain a lateral view to ensure the plate is oriented at a 45° angle. Also, assess tubercle reduction to ensure restoration of calcaneal length. If plate position and tuberosity reduction are adequate, perform additional fixation through the plate into the tuberosity fragment. The authors' experience is that at this point the tubercle is stable and screws do not need to be placed into the constant fragment.

Once the tuberosity is anatomically reduced to the constant fragment, attention is turned back to the posterior facet. Having the tubercle reduced and out of the way allows for mobilization of the posterior facet, facilitating easier articular reduction. Use an elevator to hold the depressed fragment reduced, and advance 2 guide wires for a 4.0 mm partially threaded cannulated screw through the fragment in a lateral-to-medial direction to achieve bicortical fixation. If it is difficult to determine anatomic position of the posterior facet, anatomically key in the lateral cortical margin of the posterior facet to the cortical margin of the floor of the sinus tarsi, as this structure is generally not comminuted. The posterior facet can then be directly visualized and a freer can be used to palpate any gaps or step-offs of the articular surface. Take care to avoid wire penetration into the posterior facet. Once the posterior facet is reduced and held in place with the guide wires, proceed with radiographic assessment using lateral, Harris, and Broden views to fully evaluate posterior facet reduction, location of guide wires, and restoration of calcaneal length and height (Bohler angle).

At this point if Bohler angle is not anatomically restored, there is likely sag between the posterior facet/tubercle and the anterior calcaneus. The next maneuver is to anatomically reduce the anterior calcaneus at the neck in proper alignment with the remainder of the calcaneal body and to fully restore hindfoot mechanics. A helpful reduction maneuver includes plantarflexion of the foot, placing the thumb at the anterior fracture line to act as a fulcrum, and using the Schanz pin to simultaneously plantarflex the heel. If this maneuver is not successful, the sinus tarsi incision may be extended and the fracture openly reduced. Once anatomic reduction of the

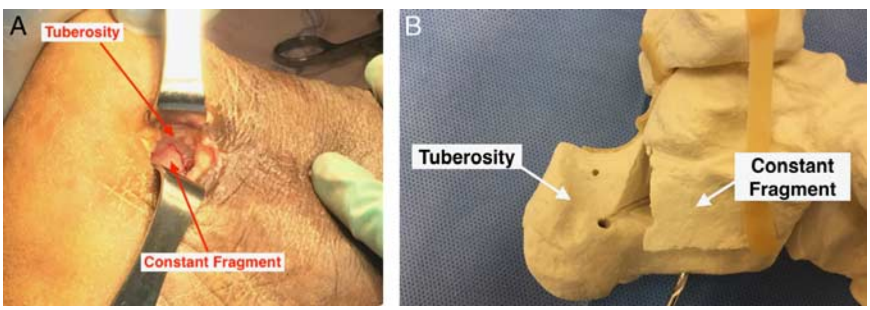

FIGURE 6. A, Through the medial incision, the tuberosity and constant fragment (arrows) are identified and reduced using push-pull technique. B, Sawbones representation of both fragments (arrows).

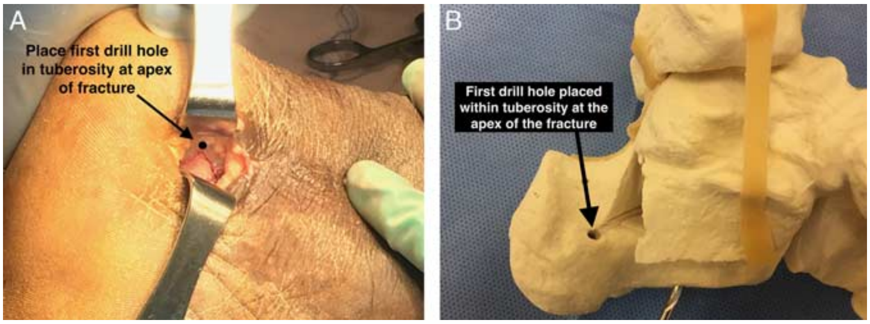

FIGURE 7. A and B, While holding the fracture reduced, a bicortical drill hole for a 3.5 mm screw is made at the apex of the tuberosity fragment (black arrows).

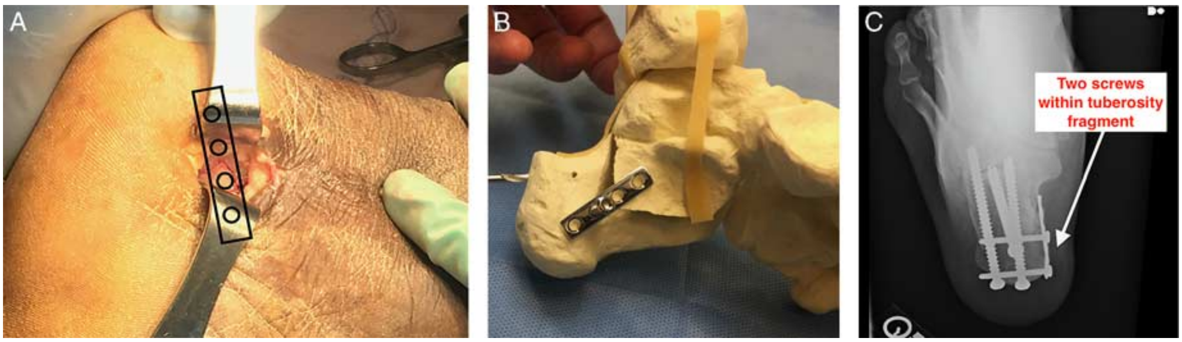

FIGURE 8. A and B, Place a 4-to-6 hole ¼ tubular plate spanning the fracture at ~45-degree angle. C, Ensure at least 2 screws will be placed within the tuberosity fragment (white arrow).

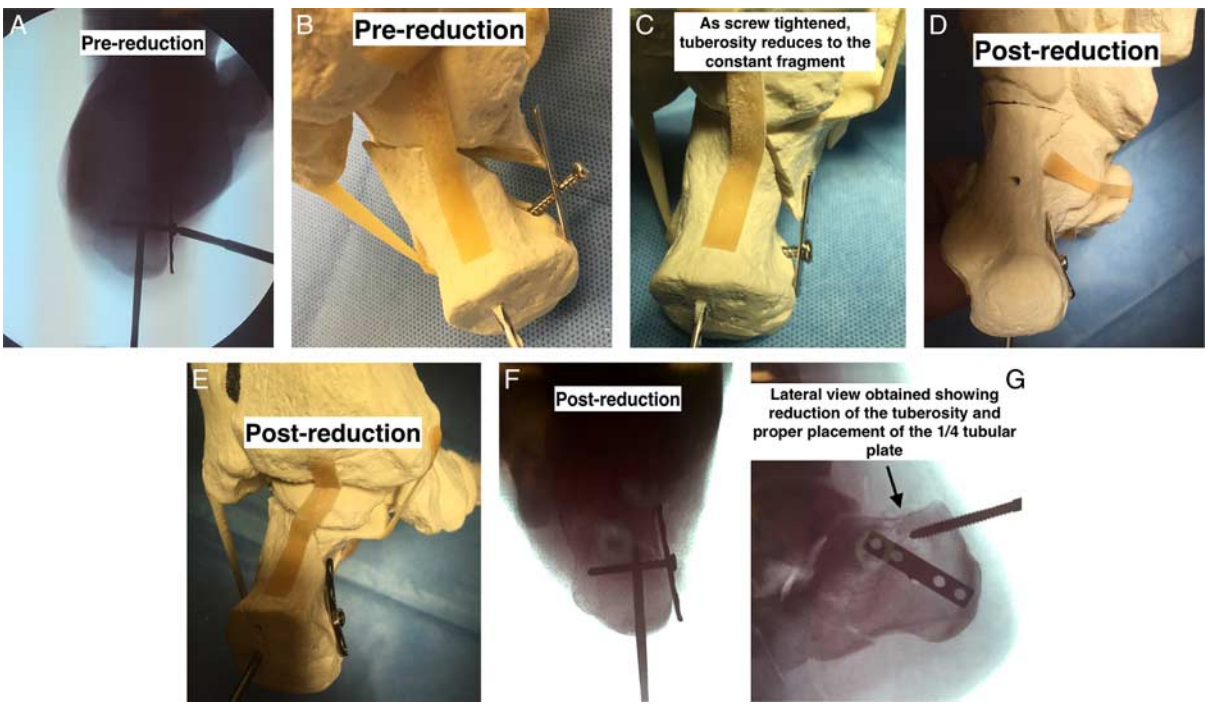

FIGURE 9. As the screw is advanced into the tuberosity (A and B), the plate acts as an antiglide buttress and reduces the heel into neutral alignment. C–E, While tightening the screw, the plate acts as a push-pull device, pushing the constant fragment and pulling the tubercle. F and G, Harris and lateral views are obtained and reveal adequate reduction of the tuberosity.

FIGURE 10. Final lateral and Harris views confirming restoration of the posterior facet, tuberosity alignment, Bohler angle (height), and calcaneal length/pitch. Raft screws are placed in a posterior-to-anterior direction, with as much divergence as possible in the anterior facet. Note that although divergence may be difficult in the sagittal plane due to space constraints within the anterior process, divergence within the axial plane is also acceptable.

anterior fragment has been obtained, the calcaneus should be restored to its native geometry as confirmed by restoration of Bohler angle and the inferior margin of the calcaneus.

The next step is fixation of the calcaneal body to the anterior fragment. This is accomplished utilizing two or three 4.5 to 5.5 mm fully threaded cannulated raft screws, directing them from the posterior tuberosity into the anterior process. Larger diameter screws increase the potential risk for screw interference, but alternatively a sinus tarsi or mini fragment plate could be used, especially if there is comminution extending into the anterior calcaneus and involving the calcaneocuboid joint. While placing the raft screws, take care to hold the reduction while an assistant advances guide wires for the cannulated screws through the calcaneus in a posterior-to-anterior direction. The goal is to maximize spread of the screws within the calcaneal body and within the anterior process. Also, placing a screw just deep to the posterior facet and anterior calcaneus provides relatively good bone stock and may prevent posterior facet sag (Fig. 10). Introduce the first guide wire within the inferior tuberosity, angled dorsally, and then introduce the second wire at the superior tuberosity, angled plantarly. The wires must be fully advanced to the subchondral bone of the anterior facet, but take care to not penetrate the calcaneocuboid joint. Obtain radiographic confirmation using lateral, Harris, and AP views of the foot. If the guide wires are in correct position, proceed with placement of 5.5 mm fully threaded cannulated raft screws over the wires (Fig. 10).

Attention is then turned back to the posterior facet. Confirm joint reduction through both direct visualization and radiographic analysis, and obtain a Harris view to ensure the guide wires are of proper length. Two 4.0 mm partially threaded cannulated screws are then placed over the guide wires, one at a time. Drilling and placement of one screw at a time avoids loss of reduction during fixation that may occur if both holes are drilled and guide wires removed at once. Fully threaded screws should be used if there is comminution at the posterior facet.

Once fixation of the posterior facet is complete, proceed with final imaging, including lateral, Harris, AP foot, and Broden views (Fig. 10). Broden view is obtained following the lateral image. With the image intensifier in the same lateral position, externally rotate the foot to 10°, 20°, 30°, and 40°, or until the joint is adequately visualized. Radiographic assessment ensures restoration of the posterior facet alignment, tuberosity alignment, Bohler's angle (height), and calcaneal length/pitch. Table 1 provides a detailed overview of the surgical technique.

RESULTS

Daws and colleagues evaluated clinical and radiographic outcomes of this duel-incision technique. They reported on 29 calcaneal fractures that met inclusion criteria consistent with the present study, and surgery for all patients included the above-mentioned approach. There was a minimum 10-week follow-up postoperatively, and no reported cases of nonunion or deep infection. There were 2 reported superficial infections treated with local wound care, and one treated with irrigation and debridement and wound care. Three of the patients required a secondary surgery—2 for hardware removal and 1 for excision of a prominent Haglund deformity. One patient eventually developed subtalar arthritis, and one patient presented with

TABLE 1. Step by Step Description of Technique

Step 1	• Positioning: Prone with operative extremity elevated on blankets • Approach: Sinus Tarsi - 4 to 6 cm incision from tip of fibula towards base of 4th metatarsal
Step 2	• Expose, mobilize, and reduce the depressed posterior facet fragment (Figure 3).
Step 3	• Proceed with medial approach to aid in tuberosity reduction (Figure 4) • Expose medial fracture line and associated tuberosity/sustentaculum fragments
Step 4	• Place schanz pin in tuberosity fragment under lateral fluoroscopy (Figure 5) • Maneuver for reduction of tuberosity using schanz pin - plantarflexion of foot (to relax achilles), followed by a posteriorly, inferiorly, and valgus-directed force
Step 5	• Return to medial approach and confirm reduction of tuberosity and constant fragment (Figure 6) • Proceed with medial internal fixation using 4-6 hole 1/4 tubular plate in antiglide manner - tuberosity will be brought out of varus into neutral alignment (Figures 7-9)
Step 6	• Return to posterior facet and confirm anatomic reduction - proceed with open reduction of facet as necessary • Hold posterior facet reduced with K-wires
Step 7	• Reduce anterior process of calcaneus to remainder of calcaneal body in order to restore Bohler's Angle
Step 8	• Proceed with fixation of calcaneal body to the anterior process • Fixation with two 4.5 mm - 5.5 mm fully threaded cannulated raft screws • Maximize spread of screws within body and anterior process (Figure 10)
Step 9	• Proceed with final fixation of posterior facet fragment using two 4.0 mm partially threaded cannulated screws
Step 10	• Obtain final imaging including lateral, Harris, and Broden's views of the calcaneus, and AP view of the foot (Figure 10)

postoperative neuropraxia with numbness in the medial calcaneal branch distribution. Radiographically, there was marked improvement in restoration of calcaneal length and height (Bohler angle) and in reduction of the posterior facet using this approach. There was also no difference found when comparing immediate postoperative versus final follow-up radiographs, confirming that there was no settling or collapse of reduction and/or fixation during the follow-up period.[19]

COMPLICATIONS

There have been no newly reported complications specific to this dual-incision approach for operative repair of displaced calcaneus fractures. Consistent with complications for other minimally invasive techniques as reported in the literature, potential complications include infection, wound problems, vascular injury, and nerve injury specific to the medial calcaneal branch of the tibial nerve. There may be a slightly increased risk of wound complications in cases of subacute fractures with hindfoot varus, as the medial skin becomes contracted with time and may be put under tension once the tuberosity is reduced back to neutral. There is also risk of posttraumatic subtalar arthritis, consistent with other reports of calcaneal fractures in the literature.

POSTOPERATIVE MANAGEMENT

Postoperatively, patients are placed in a bulky Jones splint and made nonweightbearing. At the 2-week postoperative visit, baseline postoperative radiographs are obtained, sutures are removed, a controlled ankle movement boot is placed, and physical therapy for range of motion is initiated; however, patients continue to be nonweightbearing until 10 to 12 weeks postoperatively. Follow-up radiographs obtained at 6 weeks postoperatively are used to determine how long the patient will continue to be nonweightbearing. If adequate healing is demonstrated at 6 weeks, patients may begin weightbearing as tolerated in the controlled ankle movement boot at 10 weeks postoperatively and wean out of the boot as tolerated. Follow-up radiographs are obtained at 12 weeks postoperatively, and patients then advance activity as tolerated, with final follow-up with radiographs at 16 weeks postoperatively.

POSSIBLE CONCERNS, FUTURE OF THE TECHNIQUE

As surgeons shift their techniques toward more minimally invasive approaches for repair of calcaneus fractures, the dual-incision technique described in this study provides a reliable and consistent way to approach these injuries in the majority of cases. The advantages of this approach are 2-fold: it reduces the size of the lateral incision from extensile to sinus tarsi only, minimizing the risk of wound complications, and it adds increased control over fracture reduction through the medial incision. With medial access, the surgeon gains the ability to directly reduce the tubercle, thereby increasing the inherent stability of the fracture by preventing loss of fixation and by preventing blockage of the posterior facet reduction due to a nonanatomically reduced tubercle fragment. These factors may improve the overall pattern of healing and patient outcomes, as supported by other studies showing improved clinical and radiographic results for patients undergoing operative repair of displaced, intra-articular calcaneal fractures.

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CME QUESTIONS

1. Identify the ideal fracture pattern for reduction and fixation using the described medial approach technique:
   a. Comminuted, tongue-type calcaneal fracture.
   b. Joint depression Sanders type II/III (A/B/C) with minimal comminution of the medial wall of the tuberosity.
   c. Joint depression Sanders type II/III (A/B/C) with significant comminution of the medial wall of the tuberosity.
   d. Nondisplaced calcaneal fracture.
2. Which plating technique is utilized through the medial approach?
   a. Compression.
   b. Bridge.
   c. Buttress.
   d. Antiglide.
3. What are the 4 most common calcaneal fracture fragments found in joint depression type fractures?
   a. Depressed posterior facet, tuberosity fragment, anteromedial constant fragment, and anterior process.
   b. Depressed posterior facet, anterior process, lateral wall, and medial wall.
   c. Anterior process, tuberosity, sustentaculum, and calcaneal neck.
   d. Anteromedial constant fragment, lateral wall, medial facet, and anterior process.
4. Which nerve is most at risk with the medial approach to the calcaneal tuberosity?
   a. Baxter's nerve.
   b. Deep peroneal nerve.
   c. Medial calcaneal branch of the tibial nerve.
   d. Medial plantar nerve.
5. Which intraoperative fluoroscopic views are most helpful with intraoperative assessment of calcaneal reduction and fixation?
   a. Lateral, Broden's, Axial/Harris, AP foot.
   b. Broden's, AP ankle, AP foot, lateral.
   c. Lateral, AP ankle, oblique ankle, oblique foot.
   d. AP ankle, lateral, axial/Harris, Broden's.

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ANSWER SHEET FOR TECHNIQUES IN FOOT & ANKLE SURGERY
CME PROGRAM EXAM
December 2018

Please answer the questions on page 202 by filling in the appropriate circles on the answer sheet below. Please mark the one best answer and fill in the circle until the letter is no longer visible. To process your exam, you must also provide the following information:

Name (please print): ______
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1. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5. Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

Your completion of this activity includes evaluating it. Please respond to the following questions below.

Please rate these activities (1 — minimally, 5 — completely)	1 2 3 4 5
This activity was effective in meeting the educational objectives	O O O O O
This activity was appropriately evidence-based	O O O O O
This activity was relevant to my practice	O O O O O

Please rate your ability to achieve the following objectives, both before this activity and after it: 1 (minimally) to 5 (completely)

	Pre 1 2 3 4 5	Post 1 2 3 4 5
Evaluate adolescent hallux valgus, including how to interpret history and physical exam findings as well as a complete radiographic assessment	O O O O O	O O O O O
Distinguish the previously described techniques to address AHV and the associated complications/limitations of those techniques	O O O O O	O O O O O
Assess the steps of our modified technique and the advantages and disadvantages that this technique offers	O O O O O	O O O O O

How many of your patients are likely to be impacted by what you learned from this activity?
O <20% O 20-40% O 40-60% O 60-80% O >80%

Do you expect that these activities will help you improve your skill or judgment within the next 6 months? (1 — definitely will not change, 5 — definitely will change) 1 2 3 4 5 O O O O O

Please list at least one (1) change you will make to your practice as a result of this activity:
______

How will you apply what you learned from these activities (mark all that apply):

In diagnosing patients O — In making treatment decisions O
In monitoring patients O — As a foundation to learn more O
In educating students and colleagues O — In educating patients and their caregivers O
As part of a quality or performance improvement project O — To confirm current practice O
For maintenance of board certification O — For maintenance of licensure O

Please list at least one strategy you learned from this activity that you will apply in practice:
______

How committed are you to applying these activities to your practice in the ways you indicated above? (1 — minimally, 5 — completely) 1 2 3 4 5 O O O O O

Did you perceive any bias for or against any commercial products or devices? Yes O No O
If yes, please explain:

How long did it take you to complete these activities? ______ hours ______ minutes

What are your biggest clinical challenges related to foot and ankle surgery?
______
______

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