Review Article

Advances in Surgical Management of Intra-articular Calcaneus Fractures

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Abstract

Intra-articular calcaneus fractures are commonly sustained after high-energy trauma, and a variety of techniques exists for anatomic reduction and surgical fixation. Traditional approaches using an extended L-shaped lateral incision with lateral plating for open reduction and internal fixation have relatively high complication rates. Common complications include hematoma formation, skin edge necrosis, wound breakdown, and superficial or deep infection. As a result, less invasive techniques have been developed in recent years, including limited-incision sinus tarsi open reduction and internal fixation, percutaneous fixation, and arthroscopic-assisted fixation. These techniques are associated with lower complication rates and equivalent clinical and radiographic outcomes in certain fracture patterns and patient populations.

The optimal management of displaced intra-articular calcaneus fractures is controversial and represents a topic of sustained interest and research for the past two decades.[1-12] Limited reports have shown improved functional outcomes and patient satisfaction with surgical treatment of intra-articular calcaneus fractures compared with nonsurgical management.[4,7] However, prospective, randomized controlled trials have shown opposing results, indicating that surgical treatment has no significant advantages compared with conservative care.[11,12] In a study by Agren et al,[11] the authors reviewed the results of patients randomized to either surgery or nonsurgical management between 1994 and 1998 and found that surgical treatment was associated with a higher risk of complications; at 1-year follow-up, the results were not superior to those of closed management. At 12-year follow-up, however, surgical treatment was associated with a reduced radiographic prevalence of posttraumatic arthritis. Meanwhile, Ibrahim et al[12] reported equivalent results in a comparison of surgical and nonsurgical management of displaced fractures at 15-year follow-up.

When calcaneus fractures are treated surgically, reduction and fixation is often challenging and is associated with relatively high complication rates.[1-3,5,6,10-12] Although traditional extended L-shaped lateral approaches for open reduction and internal fixation (ORIF) offer good fracture visualization and direct reduction of the posterior facet fragment and lateral wall, they also have high rates of wound complications and infection of up to 37% and 20%, respectively.[1-3,6,13] The vascular supply of the lateral hindfoot is dependent on the lateral calcaneal branch of the peroneal artery and is particularly vulnerable to disruption after extended L-shaped lateral approaches.[14,15]

Recent, less invasive surgical techniques for treating displaced calcaneus

JAAOS Plus Webinar

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fractures have been undertaken in an attempt to help reduce complications and improve recovery when surgery is indicated.[16-22] These early investigations reported lower complication rates and promising clinical and radiographic outcomes in certain fracture patterns and patient populations.[16-22] Innovative techniques include limited-incision sinus tarsi ORIF, percutaneous stabilization with pins and/or screws, and arthroscopic-assisted fracture reduction. A thorough understanding of the clinical and radiographic anatomy of the calcaneus and its articulations is crucial when attempting less invasive procedures for intra-articular calcaneus fractures. These emerging techniques may be beneficial in patients with soft-tissue compromise, multiple comorbidities, and displaced intra-articular fractures with minimal comminution. However, further research is needed to determine the ideal candidates for these procedures, as well as long-term outcomes.

Surgical Techniques

The primary indications for using less invasive approaches for the surgical treatment of calcaneus fractures include displaced Essex-Lopresti fractures, Sanders type II fractures, Sanders type III fractures in patients with multiple comorbidities, and fracture variants with minimal posterior facet fragment comminution. Relative indications include patients with diabetes, a history of smoking, and/or obesity. Percutaneous techniques are preferred in patients with peripheral vascular disease or severe soft-tissue compromise.

A critical aspect of less invasive techniques is surgical timing. We have found that fractures that are more than 3 to 4 weeks from the time of injury are more difficult to treat through small incisions because of early healing. We prefer to use less invasive techniques within 2 weeks from the time of injury because the fracture fragments remain relatively easy to manipulate and reduce with the use of ligamentotaxis. Minimally displaced Sanders type I fractures can be managed with nonsurgical care. Multiple techniques exist for surgical repair of Sanders type II and III fractures, and Sanders type IV fractures with substantial posterior facet comminution may benefit from ORIF with primary subtalar arthrodesis in order to prevent the need for late secondary surgery, thus avoiding increased costs and lost time from work.[9]

Limited-incision Sinus Tarsi Technique

The rationale behind the limited-incision sinus tarsi approach is to minimize soft-tissue dissection while still allowing fracture reduction and stabilization. A small 2- to 4-cm sinus tarsi incision permits direct visualization of the posterior facet fragment for reduction, as well as of the anterolateral fragment and the lateral wall. This approach allows for the insertion of a small, low-profile plate if needed and decreases dissection and elevation of the peroneal tendons, thus theoretically lowering the risk of tendon irritation and subluxation. Because the sural nerve is largely avoided, the risk of postoperative neuralgia or neuroma formation is minimized. The sinus tarsi incision is an extensile and utilitarian incision that can be used acutely to visualize and treat dislocated peroneal tendons; conversely, the incision can later be used should subtalar arthrodesis or tendon débridement be required. In addition, the sinus tarsi incision may be modified and be of variable length, depending on the characteristics of the fracture. It also contributes to the comfort and anticipated learning curve of the surgeon. As such, this incision offers the advantages of being considered less invasive in some cases and minimally invasive in others, with the overall goal of reducing surgical trauma to the patient.

During surgical preparation, patients are placed prone or in a lateral position using a beanbag or alternative positioner with a thigh tourniquet.[17,18,23,24] A 2- to 4-cm incision is made over the sinus tarsi along a line from the tip of the fibula to the base of the fourth metatarsal (Figure 1). The extensor digitorum brevis is retracted cephalad to permit exposure of the sinus tarsi and direct visualization of the posterior facet of the calcaneus. A Schanz pin is then placed through a stab incision in the posteroinferior calcaneal tuberosity from lateral to medial to allow for distraction, provide control of the tuberosity fragment, and aid reduction. After removing any fibrous debris and fat from the sinus tarsi, the lateral wall and the posterior facet fragment are mobilized using a knife or small elevator. Care is taken to avoid significant dissection of the peroneal tendons that are retracted posteriorly as needed. A small elevator or lamina spreader is placed under the fragment and manipulated to ascertain the amount of reduction necessary, and a Kirschner wire (K-wire) is inserted

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Figure 1

A B C

Preoperative sagittal (**A**) and axial (**B**) CT images of the left calcaneus in a 33-year-old male laborer with a displaced intra-articular calcaneus fracture after a fall from a 10-foot ladder. **C**. Clinical photograph demonstrating planned incisions for the sinus tarsi approach and Schanz pin insertion into the posteroinferior aspect of the calcaneal tuberosity.

through the fragment directed toward the sustentaculum to provisionally hold the fragment reduced (Figure 2, A and B). Calcaneal alignment and length are restored, along with correction of the varus angulation using the Schanz pin under manual control with fluoroscopic guidance. Another option is placement of a transcalcaneal pin with a traction bow attached; this action allows distraction and realignment of the posterior tuberosity.

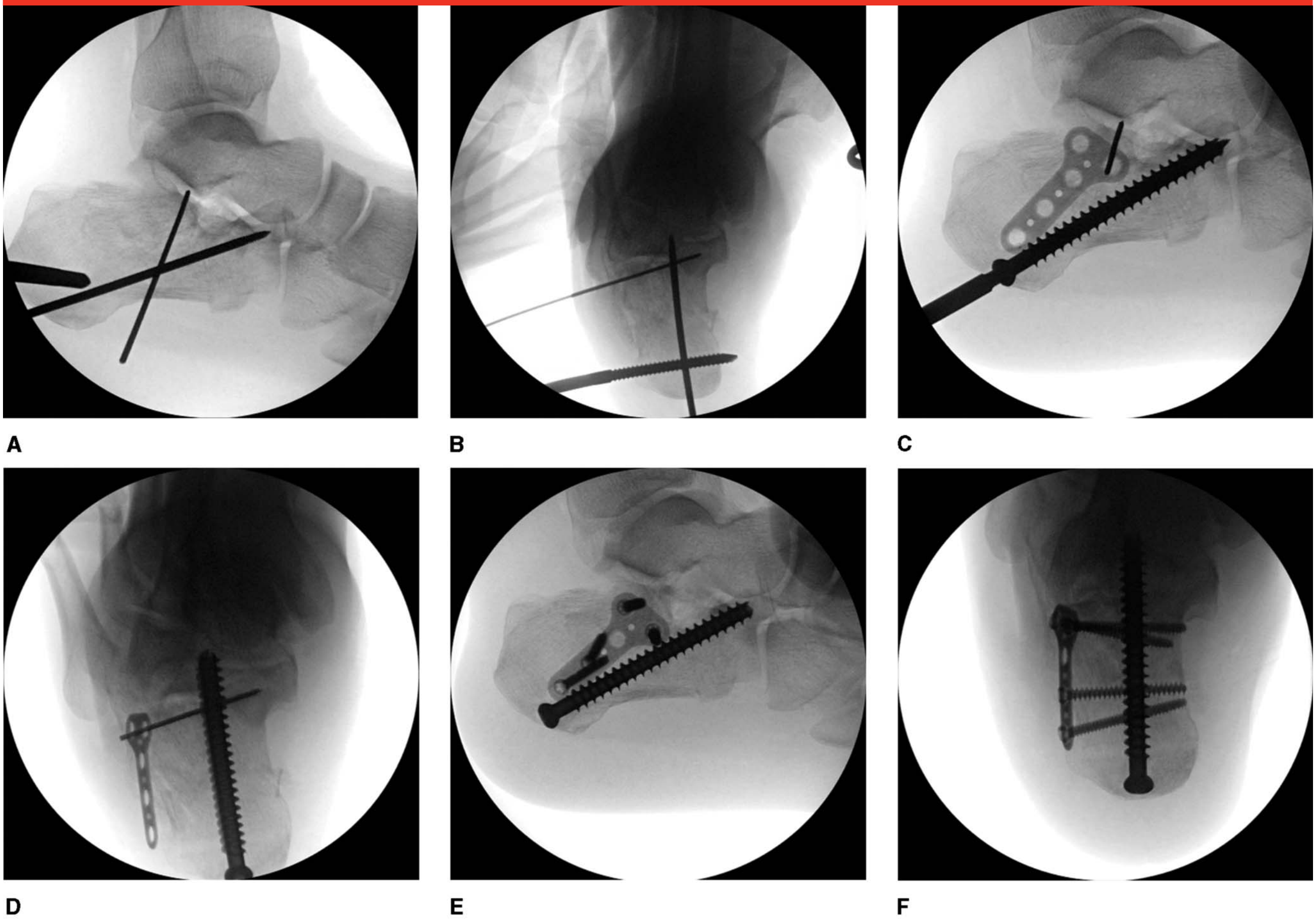
Using fluoroscopy to check alignment and length, two guide pins from a large cannulated screw set are placed from the calcaneal tuberosity into the anterior distal portion of the calcaneus (Figure 2, C and D). The fracture fixation construct may be tailored to the individual fracture pattern. In general, one to two screws are used from lateral to medial to engage the sustentaculum; in addition, one or more large cannulated screws are inserted percutaneously, running from posterior to anterior. Fully threaded screws are preferred to maintain axial length. The screws running lateral to medial are used to restore calcaneus height and to stabilize the posterior articular facet. The large, percutaneous screws are directed from the posterior aspect of the calcaneal tuberosity to the anterior aspect of the calcaneus to restore and stabilize axial length and alignment. A buttress screw may be added from the tuberosity extending up to the subchondral bone of the posterior facet fragment to act as a "kickstand" if additional support is needed to maintain height. Alternatively, low-profile plates and screws can be used in place of a "kickstand" screw.

A small full-thickness envelope of soft tissue is created from the posterior facet and directed toward the posterior calcaneal tuberosity using an elevator. A low-profile calcaneal plate may be inserted into the envelope and positioned in place with the most posteroinferior hole in line with the incision used for the Schanz pin (Figure 2, E and F). Plate fixation allows for stabilization of calcaneus height with three to four screws inserted into the tuberosity fragment and the anterolateral fragment. The incision is closed in a layered fashion, and patients are placed in a posterior mold splint (Figure 3).

Sutures are removed 2 weeks after surgery, followed by transition into a non–weight-bearing, tall controlled ankle motion (CAM) boot. Range-of-motion exercises are initiated at 2 weeks in the tall CAM boot to help decrease the occurrence of arthrofibrosis. Eight weeks after surgery, progressive weight bearing is started in the tall CAM boot, in addition to physical therapy. Twelve to 16 weeks after surgery, patients are weaned out of the tall CAM boot into normal shoes, followed by increasing activity but no running or jumping. At 16 weeks, patients are released to full activity to tolerance pending radiographic evidence of fracture union.

Individual techniques for less invasive fixation of calcaneus fractures have been described,[16-22,25] with all techniques focusing on limited incisions and decreased soft-tissue dissection while maintaining fracture reduction and stabilization. In a study by Weber et al,[26] the authors compared 24 patients with a Sanders type II or III fracture treated with a limited sinus tarsi approach and screw fixation with 26 patients who were managed using an extended L-shaped lateral approach and plating. Anatomic reduction was achieved in both groups, with equivalent functional outcomes. The group undergoing the less invasive method had decreased surgical time by 52 minutes, with no cases of hematoma, wound breakdown, or sural nerve symptoms. However, this same group also had more minor secondary procedures, and removal of heel screws was necessary in 10 of the 24 patients (42%).

Figure 2



Intraoperative lateral (**A**) and axial (**B**) radiographs of the heel demonstrating provisional fixation of the posterior facet fragment into the sustentaculum with a 1.6-mm Kirschner wire after reduction along with guidewire placement for a large cannulated screw from the posterior tuberosity into the anterior aspect of the calcaneus. Lateral (**C**) and axial (**D**) radiographs of the heel demonstrating insertion of a large, fully threaded 7.3-mm cannulated screw and provisional placement of a five-hole T-shaped low-profile calcaneus plate (Mini-Calc, Acumed). Lateral (**E**) and axial (**F**) radiographs of the heel demonstrating the final fracture fixation construct with four 3.5-mm screws placed through the plate into the tuberosity and anterolateral fragments. The most posterior and inferior screw is placed through the Schanz pin stab incision previously used.

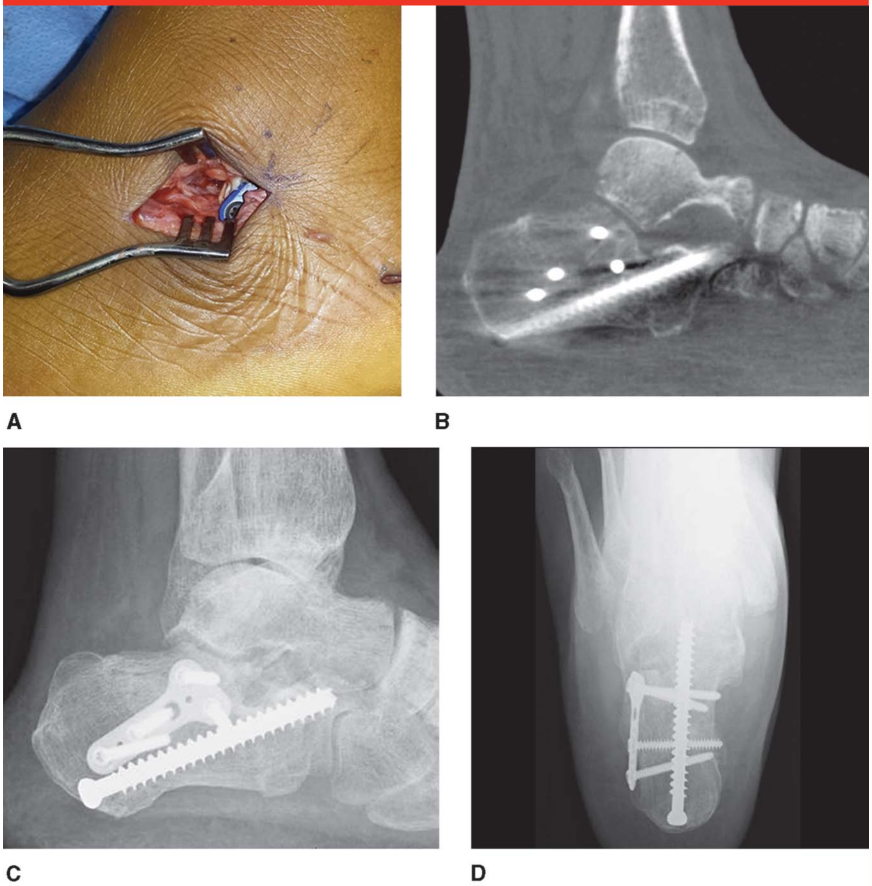
Kikuchi et al[17] reviewed 22 calcaneal fractures treated using a limited limited-incision sinus tarsi approach; restoration of the Böhler angle and calcaneal width was achieved for all cases. Three cases (13.6%) of superficial wound infection were managed with local wound care and oral antibiotics, and one patient underwent revision surgery for symptomatic hardware removal. In this series, a 2- to 5-cm incision was made and a wide, nonstandardized array of fixation devices was used, including a one-third tubular plate with screws, a combination locking/nonlocking plate with screws, K-wires, or large, fully threaded cannulated screws. Nosewicz et al[23] performed a CT-based study of 22 calcaneal fractures treated with a mini-open sinus tarsi approach (ie, 3- to 5-cm incision) and six-hole, 2.4-mm lateral plate fixation with percutaneous 5.5-mm screws. CT scans were obtained immediately after surgery and again at 1-year follow-up to evaluate fracture reduction and stability. In 14 cases (64%), postoperative posterior facet and calcaneocuboid joint reduction was found to be good (ie, step-off <1 mm, defect <5 mm, angulation <5°), with no loss of reduction at final follow-up. The final mean American Orthopaedic Foot and Ankle Society (AOFAS) score was 86, with a superficial wound infection in three patients (14%) that was managed with additional open débridement in two of the patients.

In a larger retrospective review of less invasive approaches compared with extended L-shaped lateral approaches for intra-articular calcaneus fractures, Kline et al[18] reviewed a series of 112 fractures (ie, 79 extended L-shaped lateral, 33 less invasive). For the less invasive technique, the authors reported significantly lower rates of wound complications (ie, wound edge necrosis and infection) and secondary surgery. In the extended L-shaped lateral group, 53% of the fractures were Sanders type II and 47% were Sanders type III, and the overall rates of wound complications and secondary surgery were 29% and 20%, respectively. In the less invasive group, 61% of the fractures were Sanders type II and 39% were Sanders type III, and the overall rates of wound complications and secondary surgery were 6% and 2%, respectively. In the less invasive group, all wound complications consisted of superficial wound dehiscence; management consisted of local wound care and oral antibiotics without surgical intervention. Clinical outcomes, foot function index scores, visual analog scale scores, and patient satisfaction rates were similar between groups. Both techniques had union rates of 100% with no noted differences in the final postoperative Böhler angle or angle of Gissane on plain radiographs. Fracture fixation and restoration of calcaneal height and alignment were achieved using one or two lateral-to-medial fragment screws and two or three large cannulated screws from the posterior aspect of the calcaneal tuberosity to the anterior calcaneus (Figure 4).

In a randomized controlled trial of 117 calcaneus fractures, Xia et al[27] compared an extended L-shaped lateral approach with percutaneous plate fixation using a limited sinus tarsi approach. The authors reported decreased surgical times (ie, 31 minutes faster) and lower wound complications in the less invasive group. All surgeries were performed within 5 to 12 days after the initial injury and used a low-profile titanium alloy plate. No wound-related problems occurred in the less invasive cases; however, in the traditional approach, eight cases (16.3%) had wound breakdown, with two cases of superficial infection. The less invasive group also had significantly higher Maryland Foot Scores with equivalent radiographic parameters at final follow-up.

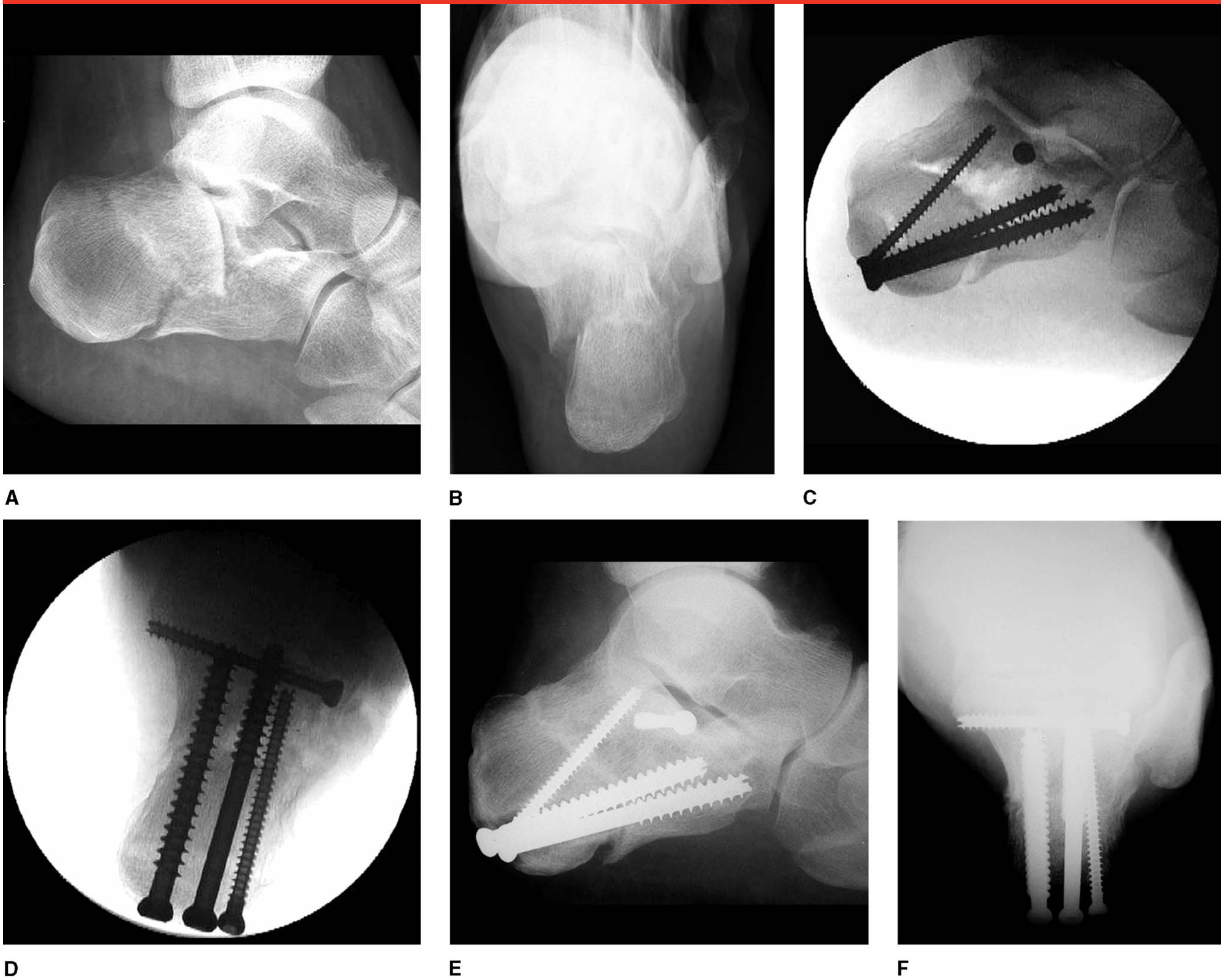
Comparing a modified, less invasive longitudinal approach with a sinus tarsi approach, Zhang et al[24] reviewed 130 cases of displaced intra-articular calcaneus fractures. The authors reported that the less invasive group had shorter surgical times (ie, 16 minutes faster), fewer wound healing complications (ie, 2.9% [less invasive] compared with 12.5% [sinus tarsi]), and equivalent outcomes for Sanders type II and III fractures as measured by AOFAS scores. In patients with comminuted Sanders type IV fractures, the authors noted better outcomes in the sinus tarsi group compared with the less invasive group. The authors' less invasive approach used a 3.5-cm longitudinal incision made over the posterior part of the lateral hindfoot along the lateral border of the Achilles tendon. Steinmann pins were used to restore calcaneal height and alignment, and the posterior facet was reduced with percutaneous leverage.

Figure 3



A, Clinical photograph of the posterior facet fragment reduction with the final plate and screws in place. **B,** Postoperative sagittal CT cut at 6-week follow-up demonstrating maintenance of the Böhler angle and calcaneal height. Lateral (**C**) and axial (**D**) radiographs of the heel 3 months after surgery demonstrating fracture union.

Figure 4



Preoperative lateral (**A**) and axial (**B**) radiographs of a right intra-articular calcaneus fracture demonstrating loss of the Böhler angle and increased calcaneal width. Intraoperative lateral (**C**) and axial (**D**) radiographs of the heel demonstrating restoration of calcaneal height and alignment using a lateral-to-medial fragment screw and large cannulated screws from the posterior aspect of the calcaneal tuberosity to the anterior calcaneus. Lateral (**E**) and axial (**F**) weight-bearing radiographs of the heel 2 years after surgery demonstrating maintenance of hardware alignment with successful fracture union. (Panels C and D reproduced with permission from Kline AJ, Anderson RB, Davis WH, Jones CP, Cohen BE: Minimally invasive technique versus an extensile lateral approach for intra-articular calcaneal fractures. *Foot Ankle Int* 2013;34[6]:773-780.)

Fracture fixation was performed using an anatomic plate and multiple compression bolts inserted percutaneously.

Percutaneous Fixation

Percutaneous fixation of calcaneus fractures can be performed using a variety of techniques with or without the addition of a limited sinus tarsi incision.[28-30] Ebraheim et al[29] described the use of an "intrafocal" reduction technique in which a Steinmann pin is placed into the fracture site from anteromedial to posterolateral to lever the primary fracture fragments into place with fluoroscopic guidance. Additional Steinmann pins and/or K-wires are inserted percutaneously from posterior to anterior and lateral to medial to hold the remaining fragments in a reduced position.[20] A calcaneal transfixion pin may be used to distract the fracture, and a bone tamp is inserted plantarly to elevate the depressed part of the posterior facet followed by pin insertion.[30] Small and/or standard size external fixation devices with pins inserted into the calcaneus and tibia or talus may also be added to increase fracture distraction if needed. Wires are cut flush with the skin and removed approximately 8 to 10 weeks after surgery.

Alternatively, a modified three-point distraction technique may be used in which three Steinmann pins are inserted into the calcaneal tuberosity, cuboid, and distal tibia.[28] Using small external fixators, the fracture is distracted to restore calcaneal height, width, and alignment. A Freer elevator is inserted percutaneously through a stab incision to aid in posterior facet reduction. Once reduction is obtained, fractures are fixed with two to three large cannulated screws directed posterior to anterior, and a smaller screw is directed lateral to medial to engage the sustentaculum.

Ebraheim et al[29] reviewed a series of 106 intra-articular calcaneus fractures treated with reduction via a limited sinus tarsi approach, followed by percutaneous transarticular pin fixation without formal internal fixation. Included in the series were 71 Sanders type II fractures (67%), 25 Sanders type III fractures (23.6%), and 10 Sanders type IV fractures (9.4%). A total of nine postoperative infections (8.5%) occurred; four patients (3.8%) had superficial wound infections, four patients (3.8%) had pin tract infections, and one patient (0.9%) had osteomyelitis. At a mean follow-up of 29 months, the average AOFAS score was 77.6 (range, 31 to 91). Radiographic evidence of arthritis was present in 41 cases (38.7%), and 6 cases (5.6%) required subsequent subtalar arthrodesis.

Stulik et al[30] reviewed a series of 287 intra-articular calcaneus fractures treated with a less invasive reduction and fixation technique using only K-wires without a limited sinus tarsi incision. All patients underwent surgery within 3 weeks from the time of injury, with 89% of the patients undergoing surgery within 2 days. Nearly anatomic reduction (ie, <2 mm residual articular displacement) with good alignment was achieved in 73.9% of fractures (212 cases). The authors reported 20 cases (7%) of superficial pin tract infections, 5 cases (1.7%) of deep infection, and 13 cases (4.5%) of loss of reduction. At a mean follow-up of 43.4 months, 72.2% of patients had good to excellent results as determined using the Creighton-Nebraska Health Foundation Assessment score; slightly better results were reported in tongue-type fractures. A total of 130 patients (73.9%) were able to return to their original occupation at a mean of 5.6 months after time of injury.

In a study by de Vroome and van der Linden,[28] the authors analyzed a cohort of 46 intra-articular calcaneus fractures treated using a three-point distraction technique with percutaneous fixation without a limited sinus tarsi incision. Using AOFAS scores, 69% of all cases had good to excellent results; with tongue-type fractures (34% of cases), 100% had good to excellent results, but only 52% of joint depression fractures (65.9% of cases) reached the same outcome. Postoperative infection occurred in one case (2.4%), and secondary subtalar arthrodesis was later required in three cases (7.3%).

Arthroscopic-assisted Reduction and Internal Fixation

Proposed benefits of arthroscopic-assisted reduction and internal fixation (ARIF) include decreased soft-tissue dissection, preservation of the local vascular supply, removal of small loose fragments, and improved direct visualization of articular cartilage lesions and fracture reduction.[31] Potential disadvantages include increased setup and surgical times, soft-tissue swelling from fluid extravasation, and technical difficulty. ARIF can be used in conjunction with limited sinus tarsi approaches for added visualization of articular cartilage and fracture reduction if needed.

Patients are positioned in the lateral decubitus position with the fluoroscopy unit posterior and oblique to the patient to allow for axial hindfoot views.[32] The contralateral knee is flexed to optimize imaging. Careful positioning of both the arthroscopy and fluoroscopy setups is important to ensure efficiency and sterility. Anterolateral and posterolateral portals are used to visualize the posterior facet using a 2.4-mm 0° arthroscope without releasing the interosseous ligaments (Figure 5). Fracture hematoma is irrigated and removed with a small shaver, and loose bodies and cartilage fragments are removed with a grasper.

The posterior facet is examined for step-offs, gaps, and/or comminution. A Freer elevator is introduced through one of the portal sites to elevate depressed fragments into place. A Schanz pin is used to help control and reduce the tuberosity fragment. K-wires are introduced under direct visualization to manipulate the superolateral depressed fragment, followed by multiple temporary K-wires placed into the superolateral and sustentacular fragments. Cannulated screws are inserted from the posterior aspect of the calcaneal tuberosity to the anterior aspect of the calcaneus to restore and stabilize axial length and alignment. Fracture fragments are then joined to the tuberosity using lateral-to-medial screws into the sustentaculum. A buttress screw can be added from the posterior tuberosity extending up to the subchondral bone of the posterior facet fragment to provide additional support and help maintain calcaneal height. Fracture reduction is examined again at the end of the procedure with both arthroscopy and fluoroscopy to ensure maintenance of articular congruity.

In a review of 22 patients with Sanders type II fractures who underwent arthroscopic-assisted reduction and fluoroscopic-guided percutaneous fixation, Woon et al[32] reported significant correction of the Böhler angle

Figure 5

A **B**

A. Intraoperative photograph demonstrating the patient positioned in the lateral decubitus position with the arthroscope in the anterolateral (AL) portal. The posterolateral (PL) portal is made in line with the anterolateral portal just 1 to 2 cm posterior to the lateral malleolus (LM). The tuberosity-joint angle is drawn with a skin marker, and a Schanz pin is inserted percutaneously into the posteroinferior calcaneal tuberosity. **B**. (Left) The arthroscopic shaver is placed posterior to the interosseous ligament (IOL) to remove small bone and cartilage fragments from the subtalar joint. (Center) Arthroscopic visualization of posterior facet fragment displacement (white arrow). (Right) Articular reduction after fragment elevation and fixation (black arrow). (Panels A and B reproduced with permission from Rammelt S, Amlang M, Barthel S, Gavlik JM, Zwipp H: Percutaneous treatment of less severe intra-articular calcaneal fractures. *Clin Orthop Relat Res* 2010;468[4]:983-990.)

without articular subsidence, in addition to improved visual analog scale scores, the Medical Outcomes Study 36-Item Short Form scores, and the AOFAS Ankle-Hindfoot Scale scores through 2-year follow-up. The authors noted that there was a learning curve for the procedure and that conversion to open reduction should be considered if percutaneous reduction attempts fail. Gavlik et al[33] analyzed 15 patients with Sanders type II fractures treated with ARIF and found no wound complications; a mean AOFAS score of 93.7 was reported at 14-month follow-up. The Böhler angle was restored and maintained on final follow-up radiographs, and no varus or valgus malalignment was noted.

Rammelt et al[19] performed percutaneous reduction and screw fixation in 61 patients with Sanders type II fractures and used arthroscopy to confirm anatomic reduction in 33 of the cases. With a minimum follow-up of 2 years, the mean AOFAS score was 92.1, and the Böhler angle and calcaneal width were reduced to the values of the uninjured side. Most patients (90.9%) underwent surgery within 10 days after the initial injury. No cases of postoperative wound edge necrosis, hematoma, or infection were noted. Sivakumar et al[31] reviewed a series of 13 displaced intra-articular calcaneal fractures treated with combined fluoroscopy and arthroscopy to aid percutaneous reduction and internal fixation. Mean postoperative improvement in the Böhler angle was 18.3°, with subsidence of 1.7° at final follow-up and good functional outcome scores.

Complications

A theoretical complication of less invasive techniques for calcaneus fracture management is inadequate fracture reduction and subtalar joint reconstruction. A limited viewing window can make it difficult to directly visualize posterior facet and anterolateral fragment reduction, thus increasing the risk of potential malreduction. Damage to the sural nerve may also occur during the placement of percutaneous screws because the nerve is not directly visualized. Potential complications of ARIF include soft-tissue swelling and wound breakdown secondary to excessive fluid extravasation. A learning curve is associated with less invasive calcaneal fixation techniques, and it is important to remember that conversion to a larger incision should be considered when there is the possibility of unsuccessful reduction and/or fixation.

Summary

The optimal treatment of displaced intra-articular calcaneus fractures remains unknown, with conflicting evidence in the literature regarding the advantages and disadvantages of surgical and nonsurgical management. Nevertheless, in those fracture patterns and in patients who may benefit from surgery, complications may be reduced by recent advances in surgical technique, including limited-incision sinus tarsi ORIF, percutaneous fixation, and arthroscopic-assisted reduction. These emerging techniques are promising, but data are limited regarding their overall utility and long-term benefits.

Less invasive approaches may also be beneficial in patients with soft-tissue compromise, multiple comorbidities, and displaced intra-articular fractures with minimal comminution. Future prospective, randomized series are needed to elucidate the precise indications, as well as the short- and long-term clinical outcomes of each procedure.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 24 and 27 are level I studies. References 9, 11, and 12 are level II studies. References 8 and 18 are level III studies. References 1-7, 10, 13-17, 19-23, 25, 26, and 28-33 are level IV studies.

References printed in **bold** type are those published within the past 5 years.

1. Buckley RE, Tough S: Displaced intra-articular calcaneal fractures. *J Am Acad Orthop Surg* 2004;12(3):172-178.
2. Gardner MJ, Nork SE, Barei DP, Kramer PA, Sangeorzan BJ, Benirschke SK: Secondary soft tissue compromise in tongue-type calcaneus fractures. *J Orthop Trauma* 2008;22(7):439-445.
3. Gougoulias N, Khanna A, McBride DJ, Maffulli N: Management of calcaneal fractures: Systematic review of randomized trials. *Br Med Bull* 2009;92:153-167.
4. Randle JA, Kreder HJ, Stephen D, Williams J, Jaglal S, Hu R: Should calcaneal fractures be treated surgically? A meta-analysis. *Clin Orthop Relat Res* 2000;377:217-227.
5. Sanders R, Fortin P, DiPasquale T, Walling A: Operative treatment in 120 displaced intra-articular calcaneal fractures: Results using a prognostic computed tomography scan classification. *Clin Orthop Relat Res* 1993;290:87-95.
6. Swanson SA, Clare MP, Sanders RW: Management of intra-articular fractures of the calcaneus. *Foot Ankle Clin* 2008;13(4): 659-678.
7. Thordarson DB, Krieger LE: Operative vs. nonoperative treatment of intra-articular fractures of the calcaneus: A prospective randomized trial. *Foot Ankle Int* 1996;17 (1):2-9.
8. **Sanders R, Vaupel ZM, Erdogan M, Downes K: Operative treatment of displaced intra-articular calcaneal fractures: Long-term (10-20 years) results in 108 fractures using a prognostic CT classification. *J Orthop Trauma* 2014;28 (10):551-563.**
9. **Buckley R, Leighton R, Sanders D, et al: Open reduction and internal fixation compared with ORIF and primary subtalar arthrodesis for treatment of Sanders type IV calcaneal fractures: A randomized multicenter trial. *J Orthop Trauma* 2014;28(10):577-583.**
10. **Bruce J, Sutherland A: Surgical versus conservative interventions for displaced intra-articular calcaneal fractures. *Cochrane Database Syst Rev* 2013;1:CD008628.**
11. **Agren PH, Wretenberg P, Sayed-Noor AS: Operative versus nonoperative treatment of displaced intra-articular calcaneal fractures: A prospective, randomized, controlled multicenter trial. *J Bone Joint Surg Am* 2013;95(15):1351-1357.**
12. Ibrahim T, Rowsell M, Rennie W, Brown AR, Taylor GJ, Gregg PJ: Displaced intra-articular calcaneal fractures: 15-year follow-up of a randomised controlled trial of conservative versus operative treatment. *Injury* 2007;38(7):848-855.
13. Abidi NA, Dhawan S, Gruen GS, Vogt MT, Conti SF: Wound-healing risk factors after open reduction and internal fixation of calcaneal fractures. *Foot Ankle Int* 1998;19 (12):856-861.
14. Cavadas PC, Landin L: Management of soft-tissue complications of the lateral approach for calcaneal fractures. *Plast Reconstr Surg* 2007;120(2):459-466.
15. **Bibbo C, Ehrlich DA, Nguyen HM, Levin LS, Kovach SJ: Low wound complication rates for the lateral extensile approach for calcaneal ORIF when the lateral calcaneal artery is patent. *Foot Ankle Int* 2014;35(7):650-656.**
16. DeWall M, Henderson CE, McKinley TO, Phelps T, Dolan L, Marsh JL: Percutaneous reduction and fixation of displaced intra-articular calcaneus fractures. *J Orthop Trauma* 2010;24(8):466-472.
17. **Kikuchi C, Charlton TP, Thordarson DB: Limited sinus tarsi approach for intra-articular calcaneus fractures. *Foot Ankle Int* 2013;34(12):1689-1694.**
18. **Kline AJ, Anderson RB, Davis WH, Jones CP, Cohen BE: Minimally invasive technique versus an extensile lateral approach for intra-articular calcaneal fractures. *Foot Ankle Int* 2013;34(6):773-780.**
19. Rammelt S, Amlang M, Barthel S, Gavlik JM, Zwipp H: Percutaneous treatment of less severe intra-articular calcaneal fractures. *Clin Orthop Relat Res* 2010;468(4):983-990.
20. **Tomesen T, Biert J, Frölke JP: Treatment of displaced intra-articular calcaneal fractures with closed reduction and percutaneous screw fixation. *J Bone Joint Surg Am* 2011; 93(10):920-928.**
21. Wang Q, Chen W, Su Y, et al: Minimally invasive treatment of calcaneal fracture by percutaneous leverage, anatomical plate, and compression bolts: The clinical evaluation of cohort of 156 patients. *J Trauma* 2010;69(6):1515-1522.
22. **Wu Z, Su Y, Chen W, et al: Functional outcome of displaced intra-articular calcaneal fractures: A comparison between open reduction/internal fixation and a minimally invasive approach featured an anatomical plate and compression bolts. *J Trauma Acute Care Surg* 2012;73(3):743-751.**
23. **Nosewicz T, Knupp M, Barg A, et al: Mini-open sinus tarsi approach with percutaneous screw fixation of displaced calcaneal fractures: A prospective computed tomography-based study. *Foot Ankle Int* 2012;33(11):925-933.**
24. **Zhang T, Su Y, Chen W, Zhang Q, Wu Z, Zhang Y: Displaced intra-articular calcaneal fractures treated in a minimally invasive fashion: Longitudinal approach versus sinus tarsi approach. *J Bone Joint Surg Am* 2014;96(4):302-309.**
25. Holmes GB: Treatment of displaced calcaneal fractures using a small sinus tarsi approach. *Tech Foot Ankle Surg* 2005;4: 35-41.
26. Weber M, Lehmann O, Sägesser D, Krause F: Limited open reduction and internal fixation of displaced intra-articular fractures of the calcaneum. *J Bone Joint Surg Br* 2008;90(12):1608-1616.
27. **Xia S, Lu Y, Wang H, Wu Z, Wang Z: Open reduction and internal fixation with conventional plate via L-shaped lateral approach versus internal fixation with percutaneous plate via a sinus tarsi approach for calcaneal fractures: A randomized controlled trial. *Int J Surg* 2014;12(5):475-480.**
28. **de Vroome SW, van der Linden FM: Cohort study on the percutaneous treatment of displaced intra-articular fractures of the calcaneus. *Foot Ankle Int* 2014;35(2):156-162.**
29. Ebraheim NA, Elgafy H, Sabry FF, Freih M, Abou-Chakra IS: Sinus tarsi approach with trans-articular fixation for displaced intra-articular fractures of the calcaneus. *Foot Ankle Int* 2000;21(2):105-113.
30. Stulik J, Stehlik J, Rysavy M, Wozniak A: Minimally-invasive treatment of intra-articular fractures of the calcaneum. *J Bone Joint Surg Br* 2006;88(12):1634-1641.
31. **Sivakumar BS, Wong P, Dick CG, Steer RA, Tetsworth K: Arthroscopic reduction and percutaneous fixation of selected calcaneus fractures: Surgical technique and early results. *J Orthop Trauma* 2014;28(10):569-576.**
32. **Woon CY, Chong KW, Yeo W, Eng-Meng Yeo N, Wong MK: Subtalar arthroscopy and fluoroscopy in percutaneous fixation of intra-articular calcaneal fractures: The best of both worlds. *J Trauma* 2011;71(4): 917-925.**
33. Gavlik JM, Rammelt S, Zwipp H: The use of subtalar arthroscopy in open reduction and internal fixation of intra-articular calcaneal fractures. *Injury* 2002;33(1):63-71.