Updated Overview of Management of the Calcaneus Fractures

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Abstract

Background: The calcaneus is the largest of seven tarsal bones and forms the prominence of the heel. Its attachment through Achilles tendon makes standing, walking and running possible. It shares in the formation of the subtalar and mid-tarsal joints which are essential for normal gait. The calcaneus has two main functions: to support the axial load of body weight and to act as a lever for the force generated by the calf muscles. Two important angles reflect the anatomy as seen on lateral radiography. Bohler’s angle shows the strongest relationship for walking dynamics. The second angle is the angle of Gissane. Regarding displaced intra-articular calcaneal fractures suitable treatment still controversial. In recent years, the traditional extensive lateral approach has been recognized as the gold standard method for treatment of intra-articular calcaneal fractures.

Keywords: Calcaneus Fractures

Background

Incidence of calcaneal fractures comprises approximately 2% of all fractures and 60% of fractures that involve the tarsal bones thus being the most common tarsal fractures. They frequently occur in young adult men with a male to female ratio of 2.4:1. Most calcaneal fractures are occupational. 72% of calcaneal fractures results from falls. Approximately 15% are open and about 10% involves spine, pelvis or calcaneus of the contra lateral side. (1)

It was stated by Stoller et al. that the increased axial load caused by falling from height -either accidental or suicidal- was the most common cause of calcaneal fractures. In motor car accidents the foot is pressed hard against the floor of the car. (1)

Management of the calcaneus fracture has been a debate among surgeons. Treatment of calcaneal fractures is of great difficulty for the following causes (1):

- Complex calcaneal anatomy.
- High energy injury mechanisms.
- Majority occur in young patients including industrial workers.
- Limited soft tissue protection.
- Small caliber limited vasculature.
- Postoperative wound complications.
- Potentially disabling malunion complications.
Non-operative Treatment:
Nonoperative treatment of an intra-articular calcaneal fracture consists of a supportive splint to allow dissipation of the initial fracture hematoma, followed by conversion to a prefabricated fracture boot with the ankle in neutral flexion to prevent an equinus contracture. Non-weightbearing restrictions are maintained for approximately 10 to 12 weeks, until radiographic union is confirmed. Early range of motion exercises are initiated especially with anterior process and extraarticular fracture (2).

Indications:
- Sanders Type I (nondisplaced).
- Comminuted nonreconstructable fractures.
- Small extra-articular fracture (<1 cm) with intact Achilles’ tendon and <2 mm displacement.
- Anterior process fracture involving <25% of calcaneocuboid joint.
- Stress fractures.
- Patients who are unfit for surgery and those with diabetes mellitus (DM) or peripheral vascular disease (PVD). (3)

Drawbacks:
- Reported rates of pain and malunion.
- Frequently results in a limited functional recovery.
- Disruption of the talocalcaneal articulation with subsequent arthrosis.
- Loss of normal extra-articular dimensions. Loss of tuberosity height or increased tuberosity width may result in peroneal tendon impingement. (4)

Operative Treatment:

Indications:
- Large extra-articular fractures (>1 cm) with detachment of Achilles tendon and/or > 2 mm displacement.
- Displaced tongue-type fractures.
- Sanders Type II and III.
- Posterior facet displacement >2 to 3 mm, flattening of Bohler angle, or varus malalignment of the tuberosity.
- Anterior process fracture with >25% involvement of calcaneocuboid joint.
  - Displaced sustentaculum fractures.
  - Fracture-dislocations of calcaneus.
  - Open fractures of calcaneus.

Techniques:
A- Open Reduction and Internal Fixation (ORIF)
- Indications:
  - Displaced intraarticular fractures involving the posterior facet or calcaneal tuberosity.
  - Fracture-dislocations of the calcaneus.
- ORIF of intraarticular calcaneal fractures aims at restoration of the overall shape of the calcaneus, anatomical reconstruction of the affected joint surfaces and stable osteosynthesis, without joint transfixation, to allow early mobilization. (5)
Fig. 1: X-ray fracture calcaneus (Sander's type IV) after conservative treatment (6).

Figure 2 Lateral incision approach for open reduction and internal fixation technique. (7)

A.1- Lateral Approach
Several approaches have been advocated but many authors favour the lateral approach. It allows direct visualization and reconstruction of the destroyed lateral wall of the calcaneus, the posterior facet of the subtalar joint and the calcaneocuboid joint. In addition, this approach permits indirect reduction of the medial wall and the sustentaculum. Adequate space will be available for the placement of hardware and bony graft required for stable osteosynthesis (6)
The principles of reduction include stabilization of the calcanealcuboid joint, the critical angle of Gissane, and the posterior facet; realignment of the calcaneal tuberosity to the sustentaculum; and finally replacement of the lateral wall. Bone grafts may be used for large defects and fixation utilizes either a custom 3.5 or a 2.7 plate that has been specifically designed for calcaneal fracture fixation. The surgery can be difficult and tedious, but it is the best method for restoring the anatomy of the calcaneus, in particular the articular surfaces. (6)

- **Timing**
  - Surgery should not be attempted until swelling in the foot and ankle has adequately dissipated, as indicated by the reappearance of skin wrinkles.
  - Surgery should be performed within the initial 3 weeks of injury, before early fracture consolidation.
  - In some cases, however, the displacement of large bony masses might cause excessive dermal tension in the medial and lateral directions, leading to deterioration of dermal circulation. In these cases, emergency operation must be attempted without delay. (6)

- **Approach**
  - The skin incision consists of two straight cuts which meet at the lateral side of the heel with curved angle the vertical arm proximaly directed downward midway between fibula and tendone Achilles to meet the distal arm which starts over the base of the fifth metatarsal and passes directly posteriorly at the upper edge of the thick, heel skin. *Attinger and Cooper* demonstrated that this “L” shaped incision is the optimal surgical incision to expose the calcaneus as it lies at the boundary between two angiosomes and this ensures maximal blood flow on each side of the incision. (8)

- **Reduction:**
  - The fracture line at the level of the angle of Gissane is identified, and the thin lateral wall is lifted gently and retracted inferiorly to expose the articular fracture fragments buried within the body of the calcaneus (Fig. 33). The superolateral fragment of the posterior facet is elevated and rotated out from within the body, immediately decompressing the remaining fracture. (6)
  - Based on preoperative evaluation of the CT scan, the surgeon should know if secondary fracture lines and thus other fracture fragments exist. These should be identified at this stage. Free articular fragments can be “fished out” of the calcaneus, cleaned of clots and placed in a saline filled cup on the back table. The calcaneus is then irrigated and all debris is removed. (6)

![Figure 3. Exposure of calcaneal fracture using Lateral Approach. (9)](image-url)
Attention then is turned to restoration of the height of the calcaneus, which is accomplished by repositioning the posterior tuberosity under the sustentaculum. This is done by placing a periosteal elevator into the fracture line in the medial wall and levering tuberosity down and shifting it medially. This reduced position can be held temporarily by passing a single K-wire through the heel and the body fragment into the sustentacular fragment. At this point, the lateral exposed portion of the sustentacular fragment is cleaned of clot, so that the superolateral articular fragment will reduce anatomically. The anterior edge of the articular surface of the medial sustentacular fragment also should be anatomically reduced to the anteromedial process if a displaced fracture exists here. This may be held in place by a K-wire. Now, the superolateral fragment should be able to sit in position easily. Sanders recommended that if the superolateral fragment is two or more pieces, it can be reconstructed anatomically using resorbable pins. Then the anterolateral corner of the superolateral fragment should line up with the posterolateral corner of the anterolateral fragment so that the angle of Gissane lines up. The superolateral fragment is then pinned into place with two K-wires. Broden views are then made, and the reduction of the joint is accepted or is rejected and repositioned until the surgeon is satisfied that the articular surface is anatomically reduced. Then 3.5mm cortical lag screws are placed from the lateral cortex towards the sustentaculum. The screws should angle slightly downward and forward to parallel the slope of the joint.

Controversy exists about grafting the defect that remains after the superolateral fragment of the posterior facet has been lifted from the body. Some studies consistently used bone grafts, whereas others used it only in selected situations or not at all. Supporters propose added mechanical strength and increased stimulation of fracture healing as justifications for using a bone graft. Those opposed to bone grafts state that the highly vascular calcaneus heals radiographically four to eight weeks after surgery in the absence of bone graft. Longino and Buckley. Found no objective radiographic or functional benefit to the use of bone graft supplementation in the operative treatment of displaced intraarticular fractures of the calcaneus. Gavlik recommended the use of subtalar arthroscopy in this stage to control the reduction of the articular surface. They found in their trials that the use of subtalar arthroscopy was superior to Broden’s views produced by image intensifier with respect to the accuracy of the images. The surgeon then directs attention to the calcaneal body. The anterolateral fragment and the posterior tuberosity are realigned to guarantee that the body is anatomically reduced.

- **Fixation**

  The surgeon then focuses on the placement of a plate. Various plates or combinations of plates may be used. The reduction is again verified on a fluoroscopic lateral view and a Harris view is done to verify that the heel is out of varus. All wires are then removed and a deep drain is placed.
• **Postoperative care:**
Sanders recommends applying a below knee non weight bearing cast before discharge. The patient returns three weeks later to remove the cast and the foot is placed in a stocking and a walking boot which is locked at 90 degrees. The patient may begin range of motion exercises out of the boot at this time, but weight bearing is not permitted for another six weeks. At nine weeks postoperatively, the patient may begin weight bearing while wearing the boot. The patient should be able to return to an active job by four and half months postoperatively. (12)

**A.2- Medial Approach:**
This approach provides direct reduction of the two major fragments of Iry fracture line because they are medial structures, with direct access to tibialis posterior bundles and flexor hallucis longus but it has lack access to anterio and posterio lateral fragments.
Also it’s difficult to handle the implants with this approach due to the presence of tendenous and neurovascular close relation. (13)

**A.3- Combined medial and lateral approaches:**
Provides accurate reduction for sustentaculum fragment and good exposure to subtalar joint but lateral wall decompression can be difficult with it and this will lead to less space for fixation of tuberosity fragment to sustentaculum, and also this approach will require mobilization of the medial neuro vascular bundle. (13)

**B- Minimal Invasive Techniques ( Percutaneous Reduction )**
Indirect closed reduction and percutaneous osteosynthesis of displaced calcaneal fractures may minimize the incidence of soft tissue related complications, but carries the risk of inadequate reduction, especially with complex fracture patterns. (14)

Indications:
- Patients with simple injury patterns or minimal displacement.
- Patients in a critical overall condition.
- Patients with local soft tissue conditions that preclude extensive approaches. (15)

**B.1- Modified Essex-Lopresti Technique :**
Indications for this technique include
i. Sanders 2C tongue-type fractures.
ii. Displaced calcaneal tuberosity fractures.
iii. Temporary stabilization of fractures with severe soft tissue compromise.
iv. Fractures in patients with relative contraindications to open surgery.
Shih et al., concluded that this technique can be performed in the presence of soft tissue swelling immediately following trauma, with a low incidence of wound infection/dehiscence. Although anatomic reduction of the articular surface cannot be achieved, this technique restores the calcaneal morphology by improving Böhler’s angle and results in acceptable functional outcomes without major complications in patients with Sanders type III joint depression type calcaneal fractures.(15)

**B.2- Percutaneous arthroscopically assisted osteosynthesis:**
Gavlik et al., reported that the short term results were excellent, as this technique provides exact assessment of the articular surface and allows anatomical reduction while adhering to the principles of minimally invasive surgery. (11)
B.3- Percutaneous calcaneoplasty through balloon-assisted augmentation with calcium phosphate cement
According to Vicenti et al., this technique had advantages as it restores a correct calcaneal height, Böhler’s angle and mechanical stability, allowing an accelerated weight-bearing activity starting from the 7th day after surgery, reducing joint stiffness and improving patients’ satisfaction. Also protect soft tissue and allow an earlier surgery without waiting for the swelling resorption. (16)

B.4- Percutaneous reduction and external fixation
The current absolute indications for the treatment of calcaneal fractures with the Ilizarov method include Sanders’s type III and IV comminuted calcaneal fractures, open calcaneal fractures, and fractures with severe soft tissue injury preventing any consideration for open surgical procedure even after the appropriate waiting period.

Disadvantages and complications of external fixation:
1) Technical difficulty and incomplete reduction of fracture fragments
2) Infection and formation of a ring sequestrum.

Fig 4. External fixator for treatment of fracture calcaneus.(17)

B.5- Semiopen Reduction and Percutaneous Stabilization
- Sinus tarsi approach
Sinus tarsi approach has many advantages as:
(i) The posterior articular facet surface was well exposed, and the restoration can be performed under direct vision.
(ii) Sinus tarsi approach facilitates bone graft, which can increase bone strength and reduce the risk of collapse.
(iii) It is easy to insert and remove the K-wires. Moreover, there is no need for extensive periosteal dissection to provide the internal fixation space.
(iv) Fewer wound-related complications. (18)
Primary subtalar joint fusion
This method is indicated in the following situations:
- Sanders’s type IV or more fragments.
- Severely comminuted fractures.
- Charcot deformity.
- Extreme obesity.
- Diabetic with peripheral neuropathy.
- Contra lateral limb amputation. (19)

In this procedure the articular surface will be removed and subchondral bone of talus is drilled to induce vascular growth and the fixation is done by one or two 6:5mm partially canulated screws and sometimes bone graft is required. (19)

Complications
WOUND-HEALING PROBLEMS AND INFECTION
Wound-healing problems and infection continue to plague the surgical treatment of calcaneus fractures. With a reported incidence between 10 and 30%, wound edge necrosis is the most common complication of open treatment of calcaneus fractures. The incidence of wound edge necrosis has declined with the popularization of the extensile lateral approach, an approach that respects the lateral angiosomes about the foot and ankle. (20)

In 2004, Zwipp and colleagues reported a 6.7% prevalence of wound edge necrosis in 553 operatively treated calcaneus fractures via a lateral extensile exposure (82). More recently, Koski and co-workers reported an 8% rate of wound edge necrosis. (21)

Most wound edge necrosis can be managed expectantly with dressing changes and careful observation. Infection of the surgical wound may be difficult to distinguish from wound edge necrosis. Most likely, these problems exist on a continuum, with simple wound edge necrosis at one extreme and deep infection at the other. As a result, much of the literature regarding wound complications combines infections and wound edge necrosis. To differentiate infections, Benirschke and Kramer used the term serious infection to describe any infection that required hospitalization, surgery, or intravenous antibiotics after the initial Fixation. (5)

Based on this definition, the rate of serious infection following open treatment of closed fractures in most reported series is approximately 0 to 20%. The rate for open fractures is comparable at approximately 0 to 21%. So, Wound edge necrosis and infections are the most common complications after open treatment of calcaneus fractures. (22)

Risk factors for wound-healing problems include single-layered closure, high body mass index, extended time between injury and surgery, smoking, diabetes, and open fractures. (23)

The best treatment for wound-healing problems and infection is prevention. This is facilitated by proper patient selection and consideration of non-operative or percutaneous techniques. If formal open reduction and internal fixation is required, the surgeon must use careful surgical technique with gentle soft tissue handling and meticulous layered closure. (23)
Fig. 5: Wound dehiscence and infection. (23)

SUBTALAR ARTHROFIBROSIS
Subtalar motion is compromised to variable degrees after calcaneus fractures. One series estimates a loss of 50% of subtalar motion in most patients with intra-articular calcaneus fractures. Motion is typically graded as a percentage of motion of the contralateral uninjured subtalar joint. (24) Most patients experience some loss of motion, which is often pronounced when walking on uneven surfaces or other situations requiring accommodative gait. Although a cadaveric study suggests that anatomic reduction of the subtalar joint and restoration of calcaneal morphology, rigid fixation, and early range of motion should improve the chances of maintaining subtalar motion, clinical studies have yet to prove these theories. (24)

PAIN
Patients with intra-articular calcaneus fractures can expect some degree of long-term pain localized to the heel or the subtalar joint. Pain may be related to subtalar arthrosis, prominent hardware, nerve irritation, malalignment of the hind foot, ankle impingement, or a variety of other sources. Multiple authors have documented a prolonged recovery for this injury, as long as 10 years after surgery. The majority of patients probably reach maximal medical improvement at approximately 1 year after injury. Therefore, we recommend waiting at least 1 year before considering additional intervention for persistent pain. (25)

SYMPTOMATIC HARDWARE
The implants utilized to rigidly fix calcaneus fractures may be prominent and symptomatic. Harvey and colleagues reported that 40% of patients that underwent open reduction and internal fixation through an extensive lateral approach required a second operation for symptomatic hardware removal. (26) As thinner, anatomically designed implants have evolved; hardware removal may be less frequently required. Indications for hardware removal include painful symptoms specifically related to the hardware, deep infection occurring after the fracture has healed, and hardware that interferes with a subsequent delayed subtalar arthrodesis. (26) Often, the patient and the surgeon have difficulty in distinguishing symptoms related specifically to hardware from those resulting from subtalar arthrosis or nerve irritation. Selective subtalar injection with lidocaine may help to distinguish the source of the pain. Symptomatic hardware removal should be conducted at least 12 to 18 months after initial fracture fixation. Typically, the exposure used to apply the implants must be utilized for removal. In the case of an extensile lateral approach, the surgeon must use care to avoid injury to the sural nerve and peroneal
tendons, which may be enveloped in scar tissue. To reduce potential complications from repeat surgery, Stamatis and Myerson described a method for percutaneous hardware removal after ORIF of calcaneus fractures, thereby avoiding an extensile approach. (26) Some surgeons advocate the use of smaller implants in order to avoid problems with prominent symptomatic hardware and to lessen the morbidity associated with hardware removal. (26)

**POST-TRAUMATIC ARTHROSIS**

The high energy imparted to the subtalar joint in most intra-articular calcaneus fractures results in some degree of post-traumatic arthrosis in most patients, regardless of the treatment used. Irreversible damage to the articular cartilage has been demonstrated to occur after a single, high-energy impact. Post-traumatic arthrosis is detected on plain radiographs by osteophyte formation, subchondral cysts, and narrowing of the subtalar joint space. Not all patients with radiographic evidence of post-traumatic subtalar arthritis are symptomatic.(27) However, advanced subtalar arthrosis has been associated with worse outcomes at 20 years in non-operatively treated calcaneus fractures. Symptomatic subtalar arthrosis can be treated successfully by subtalar fusion. (28) Other risk factors for late subtalar fusion arthodesis included male gender, workers’ compensation status, heavy labor, fracture patterns with a Böhler’s angle less than 8, and Sanders’ type IV fractures.

Late arthrodesis is relatively simple in the presence of arthrosis alone if the overall morphology has been restored in the index procedure; calcaneal malunion requires adjunctive procedures in addition to subtalar arthrodesis to optimize hind foot and ankle function. Avascular segments should be replaced with corticocancellous blocks to maintain height and length of the heel to preserve normal ankle mechanics and function. Malalignment of the hind foot may result in abnormal joint mechanics at the adjacent ankle and Chopart’s joints, and patients may develop tibiotalar arthritis or midfoot arthritis. Incongruity or arthrosis of the calcaneocuboid joint is actually fairly well tolerated, and isolated fusion of this joint is rarely indicated. (28)

**COMPARTMENT SYNDROME**

Compartment syndrome occurs in approximately 10% of all calcaneus fractures and can lead to claw toe deformity or neurologic sequelae and pain in about half of affected patients. (29) Compartment syndrome following isolated calcaneus fractures is typically confined to the deep medial component and is distinct from compartment syndrome of the foot. A comprehensive compartment syndrome of the foot is a surgical emergency, absolutely necessitating compartment releases, but the isolated medial calcaneal compartment syndrome typically is not. Even if missed, the worst case scenario is development of claw toe deformities. However, in the event that disproportionate pain is present, decompression may be warranted. Vigilance is imperative for early diagnosis and rapid decompression when indicated.(29)

**NERVE INJURY**

Nerve injury may occur with the initial injury or be the result of iatrogenic injury during open reduction and internal fixation. With the extensile lateral approach, the sural nerve is at risk for injury at the two extremes of the incision. The medial approach threatens the calcaneal branch of the tibial nerve. Harvey and colleagues reported a 2.8% postoperative sural nerve irritation after an extensile lateral approach. Sural nerve injury can be avoided with careful dissection at the proximal and distal ends of the incision to identify and protect the nerve at both locations. If the sural nerve is inadvertently lacerated or transected during the surgical approach, some surgeons recommend that the nerve should be resected far proximal to the ankle to prevent the formation of a painful neuroma in the region of the incision. (29,30)
DEEP VENOUS THROMBOSIS
The incidence of DVT associated with calcaneus fractures is unknown. As patients often face a period of relative immobility before and then immediately after surgery, it is likely that they may benefit from mechanical and pharmacologic prophylaxis although this is not proven. Low-molecular-weight heparin is generally avoided in a patient treated with an extensible lateral approach as it may increase hematoma formation under the flap. Low-dose unfractionated heparin (5000 units twice per day) may be a viable alternative. (31)

AVASCULAR NECROSIS
Rarely, necrosis of the avascular posterior facet fragments may occur, but if enough time is allowed for revascularization, collapse is rare. The joint may sag from bearing weight too early, which is usually heralded by pain. These complications develop in a small number of patients despite appropriate care, and specific factors can usually be attributed to the failures, including displacement of the original fracture, dislocation, open fracture, infection, or premorbid factors such as systemic health problems (diabetes, peripheral vascular disease, or immunocompromised status) and smoking. Successful salvage, when indicated by symptoms, usually requires excision of necrotic bone, restoration of calcaneal alignment, and limited hind foot arthrodesis. Bone grafting may also prove necessary to preserve hind foot height. (31)

MALUNION
Malunion of calcaneus fractures can occur with both operative and non-operative treatment. Malunion can be divided into two broad categories. Intra-articular malunion refers to an incomplete reduction of the subtalar joint. Extra-articular malunion affects the length, height, and width of the calcaneus. Intra-articular malunion may be related to the development of post-traumatic arthrosis. (32) Extra-articular malunion may result in complications such as peroneal irritation, inability to wear normal shoes, and adjacent joint arthrosis. (32)

NONUNION
Nonunion of calcaneus fractures is rare. Zwipp and colleagues reported a nonunion rate of 0.4%. (61) Myerson and Berger reported an isolated case of ununited sustentacular fracture. Patients with suspected nonunion can be evaluated with CT with some limitations when operative fixation has been used. If symptomatic nonunion is identified, treatment requires hardware removal, debridement of fibrous tissue and avascular or infected bone, bone grafting, and rigid compressive fixation. (61)

PERONEAL OR ANKLE IMPINGEMENT
Impingement of the peroneal tendons can be caused by residual lateral wall displacement or calcaneal malunion that constricts the peroneal tunnel and results in symptomatic tendonitis or restricted and painful inversion or eversion. The tendons are effectively subluxated in this instance, but they can also be frankly dislocated. If selective injection, casting, and shoe wear modification are not helpful, a decompressive lateral wall exostectomy is often successful in relieving symptoms. (72)

Evaluation of the surgical outcome:
The evaluation was done by clinical and radiological assessment; clinical assessment of the functional outcome was done by A.O.F.A.S hindfoot scale and the radiological assessment was done by comparing between pre and postoperative radiological parameters like Bohler and Gissane angles and their correlations with the A.O.F.A.S hindfoot scale end score.
This scale grades ankle, subtalar, talonavicular, and calcaneocuboid joint levels and may be applied to ankle replacement, ankle arthrodesis, ankle instability operations, subtalar arthrodesis, subtalar instability operations, talonavicular arthrodesis, calcaneocuboid arthrodesis, calcaneal osteotomy, calcaneus fracture, talus fracture, and ankle fracture. (74)

A score of 100 points is possible in a patient with no pain, full range of sagittal and hindfoot motion, no ankle or hindfoot instability, good alignment, ability to walk more than six blocks, ability to ambulate on any walking surface, no discernible limp, no limitation of daily or recreational activities, and no assistive devices needed for ambulation. Fifty points were assigned to function, 40 to pain, and 10 to alignment. (74)

The ankle-hindfoot score According to American orthopedic foot and ankle society results were graded as excellent if score is 95 and above, good between 94 and 75, fair between 74 and 51 and poor score if 50 and lesser. The excellent and good results considered as satisfying results while the fair and poor results were considered unsatisfying. (74)

References.


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