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Special Article

Intra-articular calcaneal fractures: Update

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Abstract

Review the literature on the current treatment of intra-articular calcaneal fractures, analyze the results of the different treatments, and provide an overview of the subject, types, and controversies of treatments, complications, and sequelae. Articles published in indexed journals were analyzed. Most were published in the past 25 years and addressed the treatment of intra-articular calcaneal fractures.

Level of evidence V; Expert opinion.

Keywords: Calcaneus; Fracture fixation, internal; Treatment outcome.

Introduction

Calcaneal fractures occur infrequently, representing 1%-2% of total fractures. Approximately 60%-75% of calcaneal fractures are displaced intra-articular fractures[1,2]. These injuries typically occur due to high-energy trauma. The most common cause is a fall from height, followed by vehicular accidents[3]. In the injury mechanism, high-energy compressive forces flatten the bone, resulting in heel widening, loss of posterior heel height due to bone collapse, and articular surface injury[2]. As it is a pathology with a high incidence of occupational, social, and economic repercussions, adequate treatment is essential. Additionally, patients may have comorbidities, including diabetes and osteoporosis, aggravating complications and worsening the expected outcome for these fractures. A debate over the effectiveness of surgical treatment in these displaced articular fractures is common. Some authors claim that non-surgical treatment has similar results[4,5]. Current evidence remains insufficient to determine whether surgical treatment is superior to non-surgical treatment. However, other authors[6] have reported that non-surgical treatment frequently yields suboptimal outcomes, contributing to subtalar joint degeneration, malalignment, and poor functional recovery. Over the past few decades, several studies have shown improved outcomes following surgical treatment. Surgical intervention may lead to improved functional recovery, according to the meta-analysis by Jiang et al.[7]. Restoring normal anatomy is associated with improved functional recovery[8]. Surgical treatment has become the preferred option for most surgeons; however, the healing process of calcaneal fractures often results in functional sequelae, regardless of the treatment used[9].

Restoration of calcaneal anatomy and articular congruity is essential. Achieving adequate reduction and stable fixation, along with early mobilization are mandatory to optimize outcomes. Thorough knowledge of calcaneal anatomy and its anatomic relationships is crucial to achieve a satisfactory surgical result.

Anatomy

The calcaneus comprises trabecular bone surrounded by a slender cortical layer. The cortical shell supporting the subtalar facets is denser than the surrounding regions and is referred to as thalamic bone. Within the cancellous bone, traction and compression trabeculae are formed. Below the thalamic portion of the calcaneus, there is an area with sparse trabeculae, which is called the neutral triangle.

This region is regarded as the most fragile part of the bone, and as a result, most fractures happen here[10]. The Gissane angle (Figure 1) is formed by the intersection of the downward and upward slopes of the superior calcaneal surface. It is located directly inferior to the lateral process

Study performed at Austral University Hospital, Buenos Aires, Argentina.

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of the talus[11]. Its normal value is 95º-105º, and its decrease reflects the presence of a compression fracture.

Classic fracture mechanism

These fractures are high-impact injuries, generally caused by falls from height, with force applied in a vertical direction from the plantar. The talus is a much denser bone that acts as a wedge on the subtalar joint. The calcaneus fractures, with collapse of its articular surface, elevation of the greater tuberosity, and widening of the lateral wall, which is the weakest. The pattern of fracture lines and the degree of comminution vary and depend on several factors, including the position of the foot at the time of impact and the patient's overall bone quality[12].

On physical examination, the patients cannot bear weight and present with edema, ecchymosis at the heels, and diffuse pain. Generally, the ecchymosis extends through the plantar arch. There is flattening, heel widening, and loss of heel height. It is mandatory to perform a complete neurovascular examination and evaluate lower-extremity tendon function. Some cases present blood blisters.

Bony evaluation in the emergency room

Anteroposterior, lateral, and oblique plain radiographs of the foot are needed[13]. A Harris view may be obtained, which demonstrates the calcaneus in an axial orientation. Bohler's angle is generally decreased, and the critical angle of Gissane is increased, on plain radiographs. Normal Bohler's angle is between 20º and 40º. Normal Gissane angle is between 130º and 145º. Computed tomography (CT) scan remains the gold standard for traumatic calcaneal injuries. It is used for preoperative planning, classification of fracture severity, and when the suspicion for a calcaneal fracture is high despite negative initial plain radiographs.

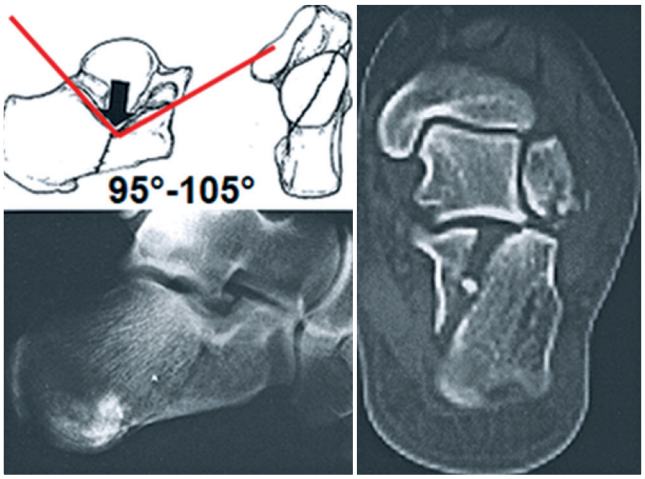

Figure 1. Gissane angle. Normal values and fracture force action.

Sanders' classification[9] is widely used, dividing the calcaneus into four columns based on fracture pattern. It is based on a coronal CT scan. There are 4 types: (Figure 2).

Type I fractures: nondisplaced bony fragments.

Type II fractures: two displaced bony fragments involving the posterior facet. Subdivided into types A, B, and C depending on the medial or lateral location of the fracture line.

Type III fractures: three displaced bony fragments. Subdivided into types AB, AC, and BC, depending on the position and location of the fracture lines.

Type IV fractures: four displaced, comminuted bony fragments.

Its limitations include limited assessment of concomitant fracture lines or soft-tissue damage.

Discussion

Conservative treatment

Lewis et al.[14] compared the outcomes of conservative and surgical treatments for displaced fractures. They noted that evidence suggests that surgical treatment could improve the functional outcomes. But they mention that the surgery may carry a higher risk of unplanned interventions. However, the authors found no difference between treatment options in the number of patients who required late reconstruction surgery

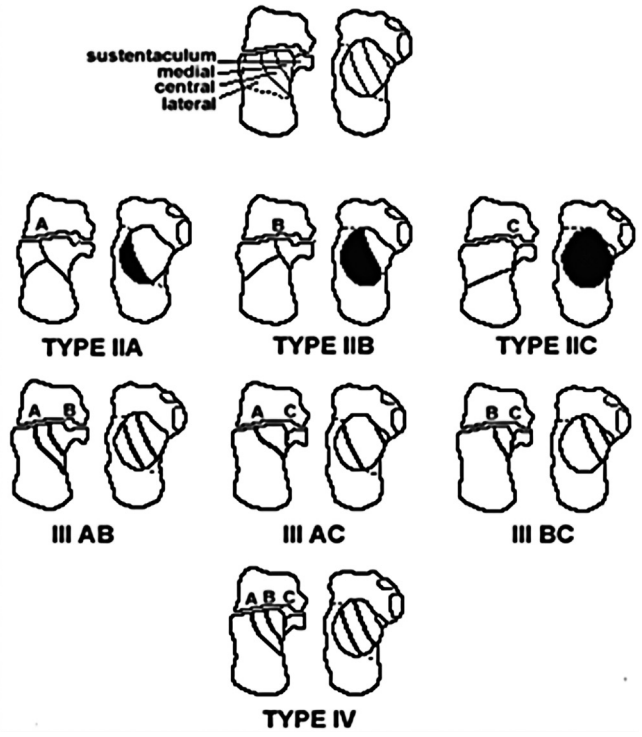

Figure 2. Sanders classification. Coronal slices in a computed tomography scan.

for subtalar arthritis. They conclude that further studies are necessary to draw more certain conclusions.

Pozo et al.[15] reported that calcaneal deformities commonly develop after intra-articular fractures that were not properly reduced or treated nonsurgically. But it can also occur after surgical treatment. There is an inverse relationship between the number of surgical cases and postoperative subtalar arthrosis[16]. This indicates that a genuine learning curve exists in the surgical management of these fractures.

Therefore, there is consensus that conservative treatment is reserved for non-displaced fractures (Sanders type I). Treatment involves rest, ice, non-weight bearing, anti-inflammatory medication, and early mobilization.

Surgical treatment

The surgical treatment of intra-articular calcaneal fractures has evolved significantly in recent years, particularly with the development of less invasive surgical approaches. Although open reduction and internal fixation (ORIF) remains the standard treatment in many cases, minimally invasive techniques (MIS), percutaneous fixation, and primary arthrodesis have emerged as valid therapeutic alternatives, especially in selected patients.

Open reduction and internal fixation via the extensile lateral approach (Figure 3) has historically been the technique of choice for displaced fractures involving the subtalar articular surface. Makki et al.[17] reported a mean AOFAS score of 75 with a mean follow-up of 10 years. This approach provides excellent exposure of the posterior facet, tarsal sinus, and sustentaculum tali, facilitating accurate anatomical reduction. Low-profile locking plates have improved construct stability and reduced mechanical failure rates, but soft tissue morbidity remains a major concern. Some authors[18] reported a mean AOFAS score of 74 points, with a minimum follow-up of 20 years. Complications associated with the lateral approach include wound dehiscence, skin necrosis, deep infection, and sural nerve injury. These complications occur in 15% to 30% of cases, particularly in patients with risk factors such as smoking, diabetes, or severe edema[19,20]. For this reason, its indication has become more selective and is now reserved for fractures with severe comminution or significant calcaneal collapse.

Minimally invasive techniques have become an intermediate option between ORIF and purely percutaneous fixation. The most commonly used approach is the sinus tarsi (Figure 4), which is performed through a 3-4 cm incision. This technique allows direct visualization of the subtalar joint without em-

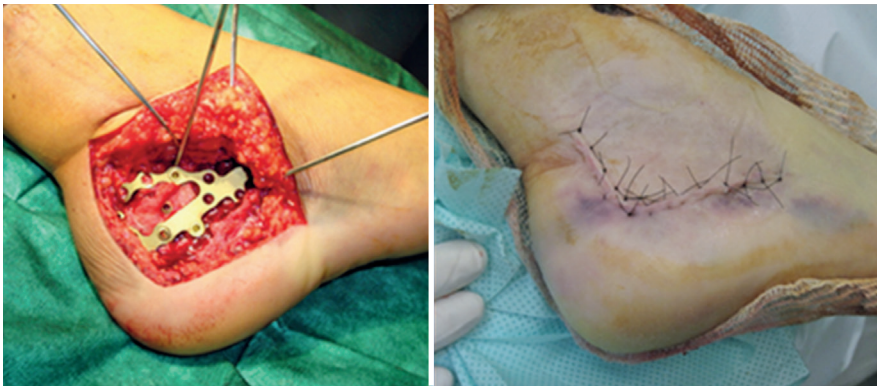

Figure 3. Lateral extensile approach.

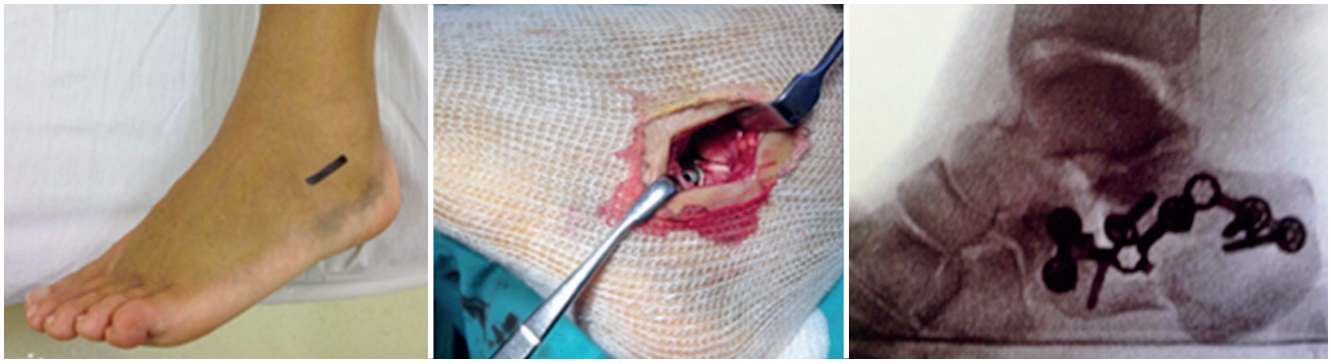

Figure 4. Sinus tarsi approach.

ploying a large incision. Clear delineation of the posterior subtalar and calcaneocuboid joints enables proper reduction of these joints, thereby preventing misalignment[21]. This technique enables a limited direct-vision-assisted anatomical reduction followed by placement of specific low-profile screws or plates. Recent studies have shown that MIS provides functional outcomes comparable to ORIF and a significant reduction in wound-related complications. [22]. In a systematic review of 271 calcaneal fractures repaired using the sinus tarsi approach, a lower incidence of wound complications and fewer sural nerve injuries were observed compared to the extensile lateral approach[23]. Furthermore, this technique allows for faster recovery and shorter hospital stays. The sinus tarsi approach is advantageous in Sanders type II and some type III fractures, where the integrity of the sustentaculum tali is preserved, and comminution is limited. However, it requires a specific learning curve, and its indication should be carefully considered in fractures with medial collapse or severe central comminution. Regarding implant removal, De Boer et al.[24] reported an overall removal rate of 35%. Of these, 66% had been treated by the tarsal sinus approach.

Percutaneous fixation is an even less invasive surgical strategy than MIS. This is performed by indirectly reducing the calcaneus via externally controlled maneuvers under fluoroscopy, followed by stabilization with cannulated screws. This technique, described by Forgon and Zadravecz[25], was developed to reduce the rate of wound complications. This method aims to restore articular congruity and bone morphology without the need for extensive incisions. It is especially indicated in patients at high risk of soft tissue complications (e.g., smokers, diabetics, immunosuppressed individuals), and fractures without severe comminution, where acceptable reduction can be achieved indirectly. Biomechanically, percutaneous fixation has been shown to provide adequate stability in simple fracture patterns, with functional results comparable to ORIF in long-term series[26,27]. However, this technique has clear limitations: indirect reduction may be incomplete in cases of severe posterior facet impaction, and intraoperative control heavily depends on image quality and surgeon experience. Driessen et al.[28], using this technique, reported in their long-term study that an AOFAS score of 76 points was achieved at a mean follow-up of 16 years.

Primary subtalar arthrodesis has gained acceptance as a valid therapeutic option in highly comminuted intra-articular fractures, particularly in elderly patients, those with preexisting osteoarthritis, low functional demand, or poor prognosis for joint reconstruction. Considered in Sanders type IV or those with significant articular damage in workers. The goal is to provide a stable, plantigrade, and pain-free hindfoot, avoiding progression to symptomatic post-traumatic osteoarthritis. It can be performed via a lateral approach or percutaneously. Depending on the degree of bone collapse, partial reconstruction of the calcaneal body may be required using structural grafts. Studies show that this technique can yield functional outcomes comparable to ORIF in type IV fractures, with lower rates of reoperation due to secondary arthritis and higher patient satisfaction in selected populations[29]. A 2022 systematic review[30] found that primary arthrodesis in severely comminuted fractures (Sanders IV) reduces the rate of late complications after ORIF, and 13.63% of ORIF cases required secondary subtalar arthrodesis. However, functional outcomes did not differ significantly between arthrodesis and ORIF.

External fixation

Talarico et al.[31] reported 25 intra-articular calcaneal fractures that were treated with external ring fixation. He described good to excellent outcomes in 23 at the final follow-up. External fixation offers benefits such as prompt weight-bearing, controlled distraction with minimal pain, mainly in soft-tissue injuries and severe comminution, and a low likelihood of complications. Frequent issues observed with external fixation include pin-related complications such as pin tract infection, neurovascular injury, and implant failure. Nowadays, it plays a role in open calcaneal fractures, those with severe soft tissue compromise, or as a bridging technique in polytrauma patients. It may be combined with percutaneous screws (hybrid configurations) as a temporary stabilization strategy that preserves hindfoot vascularity during damage control.

Table 1 summarizes the therapeutic options and considerations by fracture type.

Surgical and post-surgical complications

Surgical treatment of intra-articular calcaneal fractures, regardless of the technique used, is associated with several complications that can significantly impact functional outcomes. These complications can generally be classified as early (surgical) and late (post-surgical), and their incidence varies depending on the surgical approach, fracture severity, and patient comorbidities.

Skin complications remain a major concern in calcaneal surgery, particularly with open approaches. Wound edge necrosis, dehiscence (Figure 5), and superficial or deep infection are the most frequent. Reported incidence ranges from 12% to 30% in extensile lateral approaches[19]. Preoperative risk factors that predispose to wound breakdown include smoking, diabetes, open fractures, high body mass index, and

Table 1. Surgical options by Sanders fracture type

Sanders fracture type	Recommended technique	Key considerations
Type I	Conservative treatment	No displacement
Type II	MIS (Sinus tarsi) / Selective ORIF	Preserved sustentaculum tali
Type III	MIS or ORIF	More comminution, visualization needed
Type IV	Primary subtalar arthrodesis / External fixation	Severe joint destruction

MIS: Minimally invasive techniques; ORIF: Open reduction and internal fixation.

closure of the incision in a single layer[32,19]. Recent studies show that MIS and percutaneous techniques dramatically reduce these complications, with deep infection rates under 3% and wound dehiscence under 5%[20,21]. Shorter surgical times, minimal subcutaneous dissection, and preservation of lateral hindfoot vascularization are protective factors.

Injuries to the sural nerve, superficial peroneal nerve, or branches of the posterior tibial nerve may occur. The incidence of transient paresthesia is approximately 5%-10%, and permanent symptoms occur in less than 2%[23]. Anatomical landmarks and precise knowledge of neurovascular pathways are essential for prevention.

One of the most frequent medium- and long-term complications is the development of subtalar osteoarthritis (Figure 6), secondary to inadequate articular reduction, cartilage necrosis, or residual incongruity. Treatment of secondary osteoarthritis may include conservative measures or surgical procedures, with subtalar arthrodesis being the most effective method for pain relief in advanced cases.

Figure 5. Wound dehiscence.

Deep infections remain a feared complication. Although their incidence has decreased with MIS and percutaneous techniques, they can still reach up to 6% with open approaches, particularly in the presence of predisposing factors such as smoking, diabetes, obesity, or open fractures[19]. Management includes prolonged antibiotic therapy, surgical irrigation, and, in advanced cases, extensive debridement or salvage arthrodesis. Table 2 presents complications associated with surgical techniques.

Table 2. Complication rates by surgical technique

Surgical technique	Wound complications (%)	Symptomatic subtalar arthritis (%)	Reoperation rate (%)
ORIF (lateral approach)	15–30	28	13.6 (due to arthritis)
MIS (sinus tarsi)	5.4	19	~6–10
Percutaneous	<5	15	Higher if inadequate reduction
Primary arthrodesis	<10	-	Low
External fixation	~10 (pin site infection)	-	Low

MIS: Minimally invasive techniques; ORIF: Open reduction and internal fixation.

Table 3. Criteria for selecting surgical approach

Patient / Fracture condition	Preferred surgical technique	Clinical justification
Healthy patient, no comorbidities	ORIF (extensile lateral approach)	Allows full anatomic reduction in complex fractures
Severe edema or soft tissue compromise	MIS or external fixation	Less soft tissue trauma
Diabetic / smoker / immunosuppressed	Percutaneous or MIS	Lower risk of infection and wound issues

MIS: Minimally invasive techniques; ORIF: Open reduction and internal fixation.

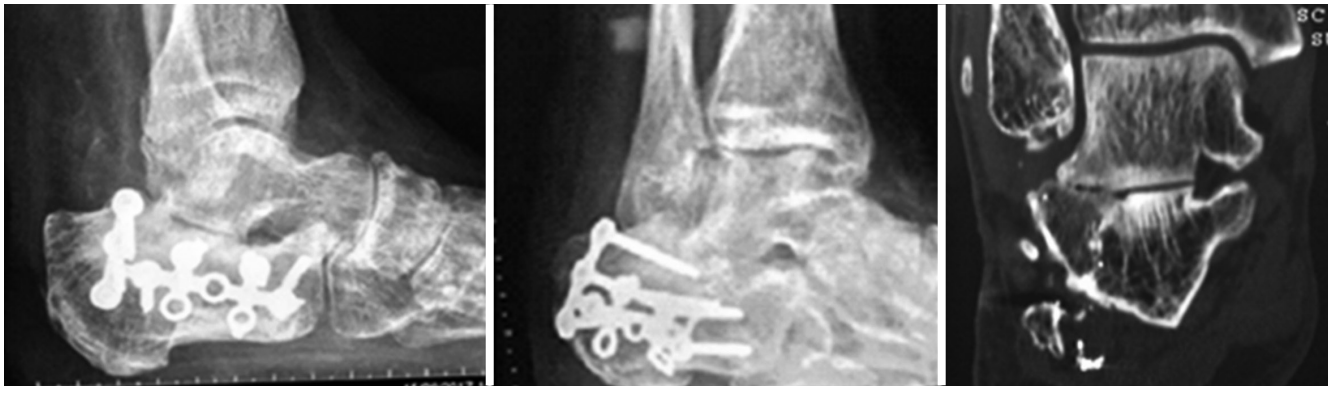

Figure 6. Calcaneal fracture sequelae. Subtalar osteoarthritis.

Conclusions

Calcaneal fractures involving the joint remain a complex issue for orthopedic management. Although no single treatment modality has proven superior in all cases, recent evidence supports surgical intervention for displaced fractures, particularly when anatomic reduction can be achieved. Minimally invasive techniques and percutaneous fixation have gained prominence due to their favorable complication profiles and functional outcomes comparable to those of traditional open reduction and internal fixation. Primary subtalar arthrodesis and external fixation are valuable alternatives in specific patient populations and fracture patterns. Table 3 summarizes the criteria for selecting an approach to these fractures. Ultimately, treatment should be individualized based on fracture type, patient comorbidities, soft tissue condition, and surgeon expertise. More well-designed comparative studies are necessary to enhance decision-making and long-term outcomes in this complex injury.

Authors' contributions: Each author contributed individually and significantly to the development of this article: JMYA *(https://orcid.org/0000-0001-5739-3130) and NR *(https://orcid.org/0000-0002-2561-8590); Conceived and planned the activities that led to the study; interpreted the results of the study and participated in the review process; performed the surgeries and data collection.

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