External Fixation with Supercutaneous Calcaneal Locking Plate For Displaced Calcaneal Fractures

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Abstract
Calcaneal fractures remain the most complicated fractures for orthopedic surgeons. Its incidence reached to 2% of all fractures and approximately 60% of all tarsal injuries. Male industrial workers are highly affected due to traumatic accidents and lead to significant economic impact due to long-term disability. The calcaneum preserves the foot and ankle biomechanics besides the coordination of muscle, tendon, ligament, and bone. The tissues within the foot, ankle and lower extremity give efficient force attenuation. Pain, swelling, discoloration around the foot and ankle, edema and inability are the main clinical manifestation. Computed tomography (CT) scan represents a good routine tool for evaluating the three-dimensional anatomy of the injury through constructing images of coronal, transverse, and sagittal planes. At first patients with calcaneal fractures received conservative treatment with early motion exercises. The foot is placed in a cast in neutral flexion to prevent contracture and elastic compression stocking to minimize dependent edema. However, this may lead to complication. Open reduction and internal fixation of intra-articular calcaneal fractures is a minimal invasive procedure rarely impairs the local circulatory condition. Mostly lateral extensile approach is used more than medial one to minimize to minimizes the sequelae of peroneal tendinitis and devascularization of the anterior skin flap and preserves the sural nerve.

Keywords
Calcaneal Fractures; Biomechanics; Computed Topography; External and Internal Fixation; Operation

Introduction
Calcaneus fractures represent the most complicated fractures for orthopedic surgeons to manage due to the complexity of various fractures, the limited surrounding soft tissue envelope, and the prolonged rehabilitation issues impacting function after successful treatment [1]. Although calcaneal fractures are rare and compose of almost 2% of all fractures in adults and approximately 60% of all tarsal injuries. Male indurial workers especially between 20 and 29 years are highly affected and lead to significant economic impact because of long-term disability [2, 3]. Their treatment is often challenging [4, 5]. Falls from height or a motor vehicle accident are the major causes of fractures which can lead to long-term disability [2]. Malunion is a main complication after conservative

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or incorrect surgical treatment of calcaneal fracture. It is characterized by subtalar joint incongruity, loss of calcaneal height, arch collapse, varus or valgus deformity of the calcaneus and widening of heel. The proper surgical methods include in situ subtalar arthrodesis, reconstruction of calcaneal thalamus and subtalar arthrodesis, calcaneal osteotomy with subtalar arthrodesis and corrective calcaneal osteotomy without subtalar arthrodesis [6]. Sanders classification system is the one that is currently used in everyday clinical practice [7].

The first operation was carried out by Norris who illustrated a compression mechanism in calcaneus fractures in 1839, and in 1843, first two types of calcaneal fractures were identified by Malgaigne. With the advancement of radiographic evaluation, several authors developed classification systems [8, 9].

The calcaneus represents the largest tarsal bone and calcaneal fractures may lead to different abnormalities. The primary disorder may arise within the calcaneus, meanwhile the secondary ones may developed in the neighboring soft tissues externally and throughout the calcaneus indirectly. The primary disorder includes congenital, traumatic, infectious, hematologic and neoplastic lesions. Arthritides and soft-tissue neoplasms that developed adjacent to the bone constitute the secondary calcaneal disorders [10].

Delayed calcaneal fractures may lead to calcaneal tuberosity avulsion fractures involved its thin posterior skin that coated the insertion of the Achilles tendon. These patients are developed skin breakdown of the posterior heel and tissue necrosis [11].

Reflex sympathetic dystrophy [12] and peroneal tendinitis and dislocation [13] are also complication of calcaneal fractures.

The manuscript illustrates the anatomy of calcaneus and ideal investigation and examination of calcaneal fractures and different treatment techniques for treatment.

### Topographic Anatomy

The calcaneus is the largest tarsal bone that forms the posterior, shorter part of the longitudinal arch of the foot. Its anterior half supports the talus serving to transmit the weight of the body from the tibia to the ground. It is composed of a thin cortical shell filled with cancellous bone, except for the calcaneal tuberosity having a condensed thickened cortex. Its shape is irregular with six surfaces presenting four articular facets that ensure contact with the corresponding bones of the tarsus. The superior surface carries the posterior, middle and anterior articular facets.

The posterior one is the largest and of clinically significant. Together with the corresponding articular surface of the talus it forms a separate joint and supports the body of the talus (Figure 1A). The inferior surface take a rectangular shape that gets wide and slightly convex towards the calcaneal tuberosity with characteristic larger medial and smaller lateral processes (Figure 1B). The lateral process facilitate attachment to the abductor digitii minimi of foot and the larger medial process to the abductor hallucis, the flexor digitorum brevis and the plantar aponeurosis. The anterior surface is fully articular, saddle-shaped ensuring articulation between the calcaneus and the cuboid. The posterior surface acquired an inferiorly based triangle; the superior third is smooth, covered with a bursa separating it from the Achilles tendon that inserted into the rough surface of the lower two thirds. The inferior third is the point of confluence of the plantar fascia and the Achilles tendon (Figure 1C) [14, 15].

**Figure 1:** A-C: Calcaneal specimen showing superior surface (A) inferior surface (B) and posterior surface (C); D & E: Calcanus showing lateral surface of the calcaneus (D) and Medial surface of the calcaneus (E).

**Abbreviations**

T: talus; STJ: subtalar joint; AchT: Achilles tendon; PB: peroneus brevis; PL: peroneus longus; CCJ: calcaneocuboid joint; Sust Tali: sustentaculum tali; FHL: flexor hallucis longus; MCT: medial calcaneal tuberosity [14].

The lateral surface continues with that of the anterior calcaneal process carrying the anterior articular facet [16]. The calcaneal tubercle located close behind and above the trochlea gives attachment to the calcaneofibular ligament. The medial surface is accentuated by the
Biomechanics

The foot and ankle biomechanics result from the coordination of muscle, tendon, ligament, and bone. The tissues within the foot, ankle and lower extremity give efficient force attenuation [19]. An antero-posterior view of the ankle and foot shows a series of angled joints with valgus at the hind foot-midfoot junction and varus at the midfoot-forefoot junction. This Z-configuration allows angular motion in the horizontal plane. In coronal section, the foot is relatively vertical in the hind foot, with an asymmetric arch becoming shallower and more horizontal as the forefoot is approached. The ankle has an articular configuration of a conic section by tibia, fibula and talus articulation that is stabilized by the deltoid ligament medially and the lateral collateral ligaments laterally. Its asymmetric surface provides greater stability in dorsal flexion and greater mobility to inversion and eversion in plantarflexion. The subtalar Joint has three facets and provides eversion, inversion, and internal rotation as talus articulate with the calcaneus. It is stabilized by components of the deltoid ligament, lateral collateral ligaments, the interosseous ligaments of the sinus tarsi, and by its lateral capsule. The talus is involved in ankle and subtalar joints where it transmits the dorsiflexion/plantar flexion at ankle joint into to inversion/eversion at subtalar joint thus the foot goes into pronation/supination in relation to ankle motion. The transmitted motion through subtalar joint depends on position of the calcaneus where it is control the foot flexibility to adapt any terrain during gait. With heel strike till midistance of gait cycle, the foot goes into pronation due to calcaneal eversion and become flexible to adapt terrain while with calcaneal inversion aided by sustentaculum tali the foot goes into supination and is locked from late stance till the end of stance phase [20] (Figure 2).

The subtalar joint divided into an anterior talar head present on the anterior and middle facets of the calcaneus, forming the acetabulum pedis with the posterior surface of the navicular bone [16]. It is supported by the articulating surfaces of the calcaneus, the navicular bone, and the ‘spring’ ligament. Abnormality of this structure can lead to flat foot deformity [21]. The size and shape of the three calcaneal facets vary between individuals, being concave of its anterior and middle facets and convex of its posterior one [22].

Following assessment the convex of the posterior facet of the calcaneus and concave facet of the talus, subtalar joint movement allowed rotation and or
Patho-anatomy and Calcaneal Fractures

Calcaneal fractures are divided into two major forms: Intra-articular and extra-articular. A precise description of calcaneal fractures, including the position and displacement of fracture fragments, which is significant for the management of these fractures. The mechanism and patho-anatomy of the acute intraarticular calcaneal fracture is produced by the axial loading. A combination of shear and compression forces produces two characteristic fracture lines. Shearing forces caused a fracture dividing the calcaneus into medial and lateral portions. Compression forces divide the calcaneus into anterior and posterior portions. Loss of calcaneal height and length are explained by this mechanism [24, 25]. Approximately 75% of calcaneal fractures result from axial loading, which is a combination of shear and compression forces. Two separate fracture lines: shear (longitudinal) and compression (transverse) fracture lines (Figure 3 A&B) [26].

Figure 3. A & B. Diagrams of the superior (A) and lateral (B) surfaces of the calcaneus showing shear (solid black line) and compression fracture lines from joint depression (blue lines) and tongue (red lines) type fractures. C-E.CT scans images. C. Coronal image showing shear fracture line (arrow) separating theanteromedial or sustentacular fragment and the posterolateral or tuberosity fragment. D. Sagittal image showing depression of the tuberosity fragment. E. Showing coronal image of a different patient showing two shear fracture lines (arrows) that separate the sustentacular, middle, and tuberosity fragments “double split.” [26].

The sagittal shear fracture line splits the calcaneus into two fragments: The antero-medial or “Sustentacular” fragment and the posterolateral or “tuberosity” fragment and may extend anteriorly to involve the cuboid facet (Figure 3 C-E). The compression fracture line runs through the coronal plane can extend medially to split the middle facet and the anteromedial fragment. Significant displacement of this fracture is prevented by the medial talocalcaneal and interossoeus ligaments. The compression fracture appears as an inverted “Y,” with the posterior limb extending horizontally toward the tuberosity as a “tongue type” fracture, or more vertically as a “joint depression type” fracture [26]. The primary difference between these...
two fracture types is the connection of the tuberosity or posterolateral fragment to the lateral portion of the posterior facet, which is present in the tongue type and absent in the joint depression type [27].

Intraarticular calcaneal fractures produce typical features, such as loss of height (impaction and rotation of the tuberosity fragment), increase in width (lateral displacement of the tuberosity fragment) and disruption of the posterior facet of the subtalar joint [28]. The osseous injuries and abnormalities such as tendons can be directly injured by sharp fracture fragments or entrapped between them [29]. Medially, there are large stretching forces, which result in fracture formation. In rare cases, compartment syndromes can occur and may be unidentified. Because of the axial load mechanism, calcaneal fractures can be associated with burst fractures of the spine, commonly at the thoraco-lumbar junction [30, 31].

Anterior process of calcaneal fractures are developed from forced inversion leading to increase tension across the bifurcate ligament, which connects the anterior process to the cuboid and navicular which is recognized on oblique views. CT is important for evaluation of anterior process of fractures. Fractures of the mid calcaneus occurred in the body, sustentaculum tali, peroneal tubercle, and lateral calcaneal process. Its mechanism of production is similar to that of intra-articular fractures and is associated with massive soft-tissue swelling and injuries to the appendicular and axial skeleton [32, 33].

The sustentaculum talus is rarely injured alone, and fracture may result from axial loading and inversion. Pain and swelling are remarked underneath the medial malleolus and with flexion of the flexor hallucis longus tendon as it passes under the sustentaculum. Axial and coronal CT images are useful for diagnosing non-displaced fractures. Injury to the flexor hallucis longus tendon and nonunion are common complications. Triggering of the flexor hallucis longus may occur from stenosis of the tendon sheath [34]. Fractures of the medial and posterior tuberosity tend to occur in elderly osteoporotic patients from avulsion of the Achilles tendon with its bony insertion [27, 35]. There is a dramatic sloughing alteration of skin if calcaneal fractures late diagnosed and treated as well as closed calcaneal fracture which required urgent surgical treatment. CT images should be obtained to assess for intraarticular or sustentacular extension [36].

Clinical Evaluation

Individuals may report a traumatic event such as a fall or jump onto the heel; description of the mechanism of injury (magnitude, location, and direction of impact) is helpful. Pain, swelling, discoloration around the foot and ankle and inability to bear weight on the injured foot are the most clinical manifestation. Individuals may complain of back or thigh pain if there has been concomitant compression fracture of the spine or femur. Examination of feet, ankles, and knees, as well as the spine, is necessary to rule out any associated injuries [16]. Inspection of the ankle may reveal deformity of the hind foot, such as shortening, widening, or angulation is common. Edema is the most evident finding and its size depends on the intensity of the impact, time of impact as well as quality of the first aid treatment.

Hematoma is a later symptom but in severe and comminuted fractures it may develop immediately after the trauma extending distally to the sole of the foot which is specific for calcaneal fractures and is known as the Mondor’s sign (Figure 4) [37].

Figure 4: A&B. Showing the “Mondor’s sign” at medial aspect of the heel (A) and plantar aspect of foot (B) [38].

Deformity and widening or broadening of the heel are detected secondary to the displacement of the lateral calcaneal border outward and accompanying edema. Blister (bullae) accompany sever types of fracture and may develop quite early after injury that caused by sever oedema, local damage to soft tissue at time of impact or combination of both which is considered as absolute contraindication for open surgery [27].

Radiographic Evaluation

These should including lateral and axial Harris views of the hind foot. An oblique view candacilitate visualizing the calcaneo-cuboid joint. Intraoperative Broden’s views, which illustrate evaluation of the posterior
facet. They are obtained by internally rotating the foot for about 45 degrees with the ankle in neutral position and angling the beam in 10-degree increments from 10 to 40 degrees off vertica [38]. Lateral plain x-ray views is the most used view evaluating ankle joint complex including ankle and subtalar joints. Angles evaluated with lateral view are Bohler’s and Gissane’s angles. The Bohler’s angle (20° – 40°) is formed by the line drawn from the tip of anterior process of the calcaneus to the tip of the posterior facet and the line drawn tangentially to the superior border of the calcaneal tuberosity [8] (Figure 5A).

The Gissane’s angle (130°-145°) is formed by the two lines that are drawn on the lateral cortex of the posterior facet and anteriorly to the anterior process of the calcaneus. In case of one side facet fracture, Double Density Sign is seen. Lateral view enables making difference between Joint depression from Tongue Type fracture [38]. Axial plain x-ray view of the heel is taken with the foot in dorsi-flexion exposing the sustentaculum tali with only the central portion of the posterior articular facet is visualized and also used for assessment of lateral wall comminution and heel varus/valgus angles (Figures 5 B-D) [14].

Figure 5: A. lateral plain X-ray of a normal ankle showing Bohler’s angle (A) angle of Gissane (B) thalamic portion of the calcaneus (C) and the neutral triangle(D). B-D: Radiographic of normal from anterior posterior (C) broaden (D) and axial heel- view (E) [29].

CT Scan
Computed tomography (CT) scan has become a routine tool for evaluating the three-dimensional anatomy of the injury. Reconstructed images are obtained in corona, transverse, and sagittal planes. CT can be helpful for preoperative planning, including deciding whether to proceed with surgical fixation or primary fusion. It helps good decision-making with regard to fracture reduction and orientation of hardware and preoperative patient discussion about the potential outcome, as highly comminuted fractures in general fare more poorly. In the sagittal plane, the dislocated tuberosity fractures can be revealed, involving the anterior processes, rotational deformities and a difference between Tongue Type and the Joint depression fractures can be determined (Figure 6A). In the axial plane, the length of the fracture up to the anterior process and calcaneocuboid joint can be revealed, as well as to the sustentaculum tali and the posterior facet, the calcaneal body can be evaluated for widening and shortening, and the tuberosity for positioning (varus, valgus) (Figure 6B) [39]. In the coronal plane is perpendicular to the posterior articular facet. All cuts are to be at least 2 mm in thickness to evaluate the calcaneus properly and it shows the number and location of the articular fragments (Figure 6C) [40]. Three-dimensional CT scanning has been studied over the past decade and although the technology is improving, the cost-benefit ratio is high [41] (Figure 6 D).

Figure 6: CT imaging showing different planes; A. Sagittal plane, B. axial plane, C. Coronal plane and D. 3D image [41].

Classification of intraarticular calcaneal fractures
The Sander’s classification system was used in the study and it assesses intraarticular calcaneal fractures, which are those involving the posterior facet of the
calcaneus [42]. This classification is based on the number of intraarticular fracture lines and their location on semi coronal CT images. This classification is useful not only in understanding typical fracture patterns of the calcaneus, but also in predicting outcome. As you move from type 1 to type 4 injuries, expected outcomes are progressively worse (Figures 7 & 8) [43].

Figure 7: Schematic drawing depicts the Sanders classification of intraarticular fractures of the calcaneus in coronal and axial views [40, 43].

Sanders [40] and Sanders et al. [43] developed a computed tomographic scanning classification of displacement of the the number and location of articular fracture fragments and divided them into three types: type I -nondisplaced, type II -displaced, and type III -comminuted.

Following studying the radiographic and CT of 120 displaced intra-articular fractures of the calcaneum, Eastwood et al. [44] reported CT of 96% of cases revealed three main fragments: sustentacular, lateral joint and body. The sustentacular fragment was often rotated into varus, the lateral joint fragment into valgus and the body fragment impacted upwards, in varus and displaced laterally. These displacement varied in the three types according to the the composition of the fractured lateral wall of the calcaneum. In type 1, lateral joint fragment is observed meanwhile type 2 exhibited both fragments in the body and lateral joint. In type 3, fragment occurred in body fragment only In type 3 fractures, an osteotomy of the lateral wall is required to allow transcalkaneal reduction of the medial wall. This reduction allows the three fragments to be stabilised by a 3.5 mm Y-shaped reconstruction plate [45].

Figure 8: CT scans coronal and sagittal views of various fracture patterns according to Sander’s classification [43].

Management

There is a great debate for choice the best course of treatment of calcaneal fracture, especially the best operative management of its displacement or operation of the intra-articular fractures [14]. Nonoperative management is required for patients over 50 years old or who have pre-existing health conditions, such as diabetes or peripheral vascular disease. Extra-articular fractures are generally treated conservatively when no impingement of the peroneal tendons and the fracture segments are not displaced (or are displaced less than 2 mm) [46]. Nonoperative treatment consists of early motion exercises and non-weight-bearing for approximately three months. The foot is placed in a cast in neutral flexion in order to prevent an equinus contracture and elastic compression stocking is used to minimize dependent edema [47]. It offers little chance of a return to normal function for displaced intra-articular fractures, the heel remains shortened and widened, the talus remains dorsi- flexed in the ankle mortise, and the lateral wall causes impingement of the peroneal tendons [48].

Operative Management

There is a much debate between surgeons about
the ideal method of treatment which varies according to the case or the surgeon. The goals of operations are to restore almost normal heel height and length, realignment of the posterior facet of the subtalar joint, and keeping of the mechanical axis of the hindfoot [49].

Open reduction and internal fixation (ORIF) should be performed within the first three weeks after the injury, before early consolidation of the fracture. An operation should not be carried out until swelling of both foot and ankle has markedly decreased [17]. The patient should be evaluated with CT and conventional radiographs. If operative intervention is indicated at that time, it may be performed as soon as the wrinkle test is positive [50]. Mostly lateral extensile approach is used more than medial one to minimize the sequelae of peroneal tendinitis and devascularization of the anterior skin flap and preserves the sural nerve (Figure 9) [47].

Kulkarni et al. [51] carried out operative management of displaced intraarticular calcaneal fractures by plating and conservative management with cast to minimize displaced fractures.

Figure 9: A&B. Photographs showing lateral approach with Kirschner wires (A) retracting full-thickness skin flap A and closed extensile lateral approach (B) [27].

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. The superolateral fragment of the posterior facet is evaluated. Height of the calcaneus is accomplished by repositioning the posterior tuberosity under the sustentaculum. 3.5-millimeter cortical-bone lag screws are placed from the lateral cortex toward the sustentaculum. The anterolateral fragment and the posterior tuberosity are realigned to ensure that the body is anatomically reduced. A low-profile lateral plate is applied to stabilize the posterior facet, the anterior process, and the posterior tuberosity then a layered closure is performed (Figure 10 A-C) [44]. Permanent fixation is then achieved with the use of cannulated lag screws inserted lateral to medial from the lateral cortical wall to the sustentaculum tali or medial cortical wall, with care taken not to evaluate the medial neurovascular and tendinous structures (Figure 10 D-E) [46].

Figure 10: Post-operative plain x-ray A. A lateral view of a standard open fashion using the extended lateral approach. B. Broden’s view of the posterior facet to show congruency. C. Axial heel view showing adequate placement of hardware [27].D &E. Plain x-ray showing Harris axial view after percutaneous insertion of cannulated screws (D) and lateral view of same ankle (E) [24].

Minimal incision with percutaneous fixation for intra-articular fractures of the calcaneus represents surgical option for high risk patients and the tongue-type fracture which is more amenable to percutaneous fixation methods [2].

The percutaneous fixation techniques for calcaneal fractures can be divided into two steps: traction and pin leverage/screw fixation. Both steps involve indirect reduction using concept of concept of “ligamentotaxis” and percutaneous stabilization with intra-operative image intensification. Minimal incision over the thalamic portion allows direct reduction then provisional fixation with percutaneously inserted Kirschner wires or cannulated guide wires under image [52].

Open treatment of calcaneus fractures is of great challenge for increased success of wound healing. Of 212 calcaneus fractures, there is only a rate of 2.7% wound healing and 4.7% of patients required secondary arthrodesis of the subtalar joint [53].

Long et al. [54] carried open reduction and internal fixation with locking calcaneal plate of calcaneal fracture (Sanders II-III) in elderly patients and observed the overall excellent to good rate was 82.6%. The mean Bohler’s angle
and Gissane's angle were 25.31° and 117.5° respectively.

Calcaneal fracture fixation with an extensible lateral approach and small incision techniques are promising outcomes and reduced the risk of soft tissue complications and improve the rate of recovery. Small incision techniques have reported promising outcomes and reduced risks for complications of the calcaneal fracture. These techniques may be beneficial to reduce the risk of soft tissue complications and improve the rate of recovery [55].

External Fixation and Indirect Reduction

Is used for reduction fixation of intra-articular calcaneal fractures. The Ilizarov technique found popularity in managing foot injuries specially calcaneal injuries otherwise the traditional external fixations that impairs local circulation. A small traction pin is placed through the tuberosity fragment, and a Kirschner traction bow and the patient is then positioned in skeletal traction similar to that used for a tibial shaft fracture reduction. External fixators are used to minimize soft tissue complications, wound, and bone dysfunction and to optimize post-traumatic functional results. Hinged external fixator allows the primary, functional treatment of the complex calcaneus fractures. A temporary triangular trans-fixation with rods is recommended to enable a preoperative computed tomography (CT) scan after soft tissue recovery. The Schanz crews are anchored at a safe distance from the fracture, and there position is indirectly performed with soft tissue with ligamentotaxis. This leads to an enhancement of fracture positioning and a relaxation of the soft tissue, and does not allow the skin on the heel to contract (Figure 11) [56].

Early external fixation restores the normal soft tissue tension and restores normal calcaneal height, length, width, coronal plane alignment and overall calcaneal architecture [57].

Super-cutaneous fixation was obtained from a previous report in which the term was used for external locking plates to treat infected fractures of clavicle and tibia in 2 stages, the 1st stage the locking plate used as external fixator till infection management or better skin and soft tissue condition and 2nd stage for definite internal fixation [58].

The lateral wall fragment was then elevated in one piece and the impacted posterolateral fragment was elevated and everted with a periosteal elevator. The fragments of the posterior facet, including the elevated posterolateral fragments and posteroomedial sustentacular fragments, were reduced according to the shape and size of the inferior articular surface of the talus and fixed temporarily with Kwires. A 4.0-mm Steinmann pin was inserted from the lateral side through a stab incision in the posteroinferior portion of the calcaneal tuberosity. Traction was applied manually along the long axis of the calcaneus to correct the deformity and provisionally held with 2.0-mm K-wires. After this, the 4.0-mm Steinmann pin was removed. The calcaneal locking plate and screws provided stable fixation acting as an external fixator where the bone and the plate are connected with the locking head screws and the distance between the plate and the skin was about 1 to 1.5 cm [50].

Figure 11: Diagram illustration intraoperative image of the external fixator mounting after the repositioning maneuver [57].

Schuberth et al [59] carried out of 24 cases of minimally invasive open reduction and internal fixation (ORIF) of intra-articular calcaneal fractures. They reported significant changes in articular step-off of the posterior facet, medial wall displacement, and the Boehler angle after the operation treatment. This led authors to

Figure 12: Post-operative plain x-ray Harris axial view shows space between plate and calcaneum (A) and lateral incision and plate positioning over skin (B) [51].
conclude that a minimally invasive approach can improve radiographic parameters consistent with the goals of restoration of articular congruity, calcaneal morphology, and calcaneal height and can give minimal risk of wound complication. 

Grala et al [60] studied two groups of patients who underwent operative treatment for articular fractures of the calcaneus, one comprising 23 patients treated by standard reconstruction and the second 19 patient having a large bone distractor. The group in whom the distractor was used had shorter operating times, and less effort was required in performing the surgery. The bone distractor, according to the authors, retracted the soft-tissue flap, helped reduce the articular and tuberosity fragment, and improved visualization by distracting the posterior talocalcaneal joint. All fractures healed well or very well.

Zhang et al [61] described super-cutaneous fixations for calcaneal fracture using an incision is made from the tip of the lateral malleolus to the base of the fourth metatarsal performed under image intensifier control with calcaneal locking plates. The screws were passed through the whole width of the calcaneus, taking precaution to avoid the injury of the medial anatomic structures. Zhang et al. [62] make a comparison between a minimally invasive lateral approach and a conventional sinus tarsi method for displaced intra-articular (Sanders Type II, III, and IV) fractures of the calcaneus. The authors reported that the minimally invasive approach led to a decrease of postoperative complication rate compared to the sinus tarsi one for Sanders type II and III injuries. However, the sinus tarsi exhibited significant improvements in functional outcomes over the minimally invasive approach, but this was limited to patients with Sanders type IV injuries. Dhillon et al. [63] evaluated twenty-five displaced intra-articular calcaneal fractures in 21 patients, aged 15-55 years and reported that MIS technique can achieve acceptable fracture reduction and can serve as the primary definitive treatment option for open fracture approach.

The ideal treatment of displaced intra-articular calcaneal fractures is still controversially discussed. Because of the variable fracture patterns and the vulnerable soft tissue coverage an individual treatment concept is advisable. In order to minimize wound edge necrosis associated with extended lateral approaches, selected fractures may be treated percutaneously or in a less invasive manner while controlling joint reduction via a sinus tarsi approach. Fixation in these cases is achieved with screws, intramedullary locking nails or modified plates that are slid in subcutaneously. Early follow-up treatment explained early rehabilitation independent of the kind of fixation. Peripheral fractures of the talus and calcaneus are result from subluxation and dislocation at the subtalar and Chopart joints [64, 65].

Al-Sayyad [66] carried out modification of supercutaneous fixation described by Zhang et. al.(2012) in 30 patients(21-55 years old, 24 Males and 6 females). The patient were positioned in lateral decubitus position, Traction was carried out by a 4.0-mm Steinmann pin inserted from the lateral to medial side through a stab incision in the postero-inferior portion of the calcaneal tuberosity. Traction was applied manually along the axis of the tibia to correct the deformity as well as assisted with pronation/supination of the foot in order to disimpact the fragments. Plantar flexion was the last step of traction which helped length restoration (Figure 13A & B). The traction was assessed radiologically by the disappearance of double density sign. Reduction of the posterior facet is carried out with a blunt tool lodged into the calcaneus under image control of the posterior tuberosity fracture reaching the inner wall of the posterior facet through the stab incision in the plantar aspect of the foot (Figure 14 A-C).

The fragments were provisionally held with 2.0-mm K-wires then the 4.0-mm then Steinmann pin was removed. With the reduction completed, the intra-operative lateral and Broden’s views, the size and position were adjusted under the image intensifier according to the reduced calcaneus. The size of the plate was fitted to the calcaneus (Figure 14 D). The screws were passed through the whole width of the calcaneus, and their number and distribution varied according to the type of fracture and the degree of comminution. Eight to nine screws were used and each screw head was locked completely into the plate hole. The anterior and posterior parts of the calcaneus carries good bone stock allow for started hold screws. The bone and the plate were connected with the locking head screws. The distance between the plate and the skin was about 1 to 1.5 cm and entry point of the screws was set approximately 1 cm below the posterior facet.Joint alignment was checked fluoroscopically and the adequacy of reduction, stability of the construct, and unrestricted subtalar movement were verified and good dressing is applied with crepe bandage. There was no need to fill the bone defect resulting from the elevated posterolateral
fragments with either bone or substitutes because the posterior facet would be supported by the locking screws beneath it. Immobilization and splinting in the current study all cases had crepe bandage with good dressing applied over the ankle (Figure 15 A-D).

Chen et al. [67] carried out fixation with plate and percutaneous screws via the mini-open sinus tarsi approach in calcaneal fractures of Sanders type I and II of 21 patients and observed all of them gained primary incision healing, without complications such as skin necrosis, wound infection, tenosynovitis of peroneus longus and brevis muscles, or fracture displacement and hardware failure. Bone union was achieved at an average of 10.5 weeks (9 to 11 weeks). The calcaneal width, Böhler angle and Gissane angle kept normal.

The authors concluded that early investigation of calcaneal fractures facilitated treatment by suitable management of either external or internal fixation. Operation gives good improvement and healing of the fractured bone.

The authors declare that there is no conflict of interest.

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