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Closed Reduction and Percutaneous Kirschner Wire Fixation of Adult Displaced Intra-Articular Calcaneal Fractures: A Narrative Review

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Abstract

The treatment of intra-articular calcaneal fractures can be divided into three categories: non-operative, open or closed reduction and internal fixation, and primary arthrodesis. The extensile lateral approach has been popular because it allows most of the fracture fragments to be directly visualized and reduced. However, complications, including wound dehiscence as well as superficial and deep infection, are common. The use of less extensive or percutaneous approaches decreases the frequency and severity of these complications, but reducing the fracture without directly visualizing the fracture lines and providing enough fixation to prevent displacement without plates are challenging obstacles to wide adoption of limited surgical approaches. Percutaneous treatment by skeletal distraction and screw fixation of displaced intraarticular fractures of the calcaneus, with functional postoperative after treatment was used in order to reduce the secondary trauma and subsequent complication rates to the soft tissues as seen in the open reduction and fixation techniques.

Keywords: Displaced intra-articular calcaneal fractures; closed reduction; percutaneous fixation; Kirschner wire; minimally invasive treatment; subtalar joint.

1. Introduction

The history of management of calcaneus fractures demonstrates an oscillation between operative treatment and non-operative intervention. Advances such as prophylactic antibiotic therapy, fluoroscopy, the discovery of the computed tomography scan, better understanding of the pathoanatomy of calcaneus fractures and improved surgical techniques have led to improved outcomes for surgical treatment in the past two decades [1].

The treatment of intra-articular calcaneal fractures can be divided into three categories: non-operative, open or closed reduction and internal fixation, and primary arthrodesis [2].

Displaced intra articular fractures are best treated operatively and the ideal treatment goals aim to achieve the following:

- Restoration of heel height and alignment,
- Realignment of the posterior facet of the subtalar joint and
- Restoration of the mechanical axis of the hindfoot [3].

The extensile lateral approach has been popular because it allows most of the fracture fragments to be directly visualized and reduced. However, complications, including wound dehiscence as well as superficial and deep infection, are common [4].

The use of less extensive or percutaneous approaches decreases the frequency and severity of these complications, but reducing the fracture without directly visualizing the fracture lines and providing enough fixation to prevent displacement without plates are challenging obstacles to wide adoption of limited surgical approaches [4].

Percutaneous treatment by skeletal distraction and screw fixation of displaced intraarticular fractures of the calcaneus, with functional postoperative after treatment was used in order to reduce the secondary trauma and subsequent complication rates to the soft tissues as seen in the open reduction and fixation techniques [5].

2. Historical Perspectives

Intra-articular fractures of the calcaneus were first described by Malgaigne in 1843. However, the accurate diagnosis of these fractures was not possible until the early twentieth century with the advent of radiography. Since then, the distinction between the tongue type and joint-depression type of fracture has been known [6–7].

In 1926, Conn recognized that fractures of the calcaneus are serious and disabling injuries in which the end-results continue to be incredibly bad. For a greater part of twentieth century, many of these fractures were treated conservatively, but in the last 20 years operative fixation has become a viable and, in many instances, superior treatment strategy owing to technological innovations in orthopedic hardware and the evolution of surgical technique. Irrespective of these advances, many fractures of the calcaneus are complex injuries, associated with wound complications and lacking a true consensus of management [6–7].

For many centuries the treatment of calcaneal fractures has been non-operative and included bandaging and elevation of the foot. The earliest published surgical attempts to reduce displaced fragments of a fractured calcaneus were by means of a pulley device, described by Clark in 1855. The first open reduction took place in an open fracture by Bell in 1882 and the first open reduction and internal fixation by a lateral approach was performed by Morestin in 1902 [8].

In 1895, the radiographic visualization of fractures was introduced and many different treatment modalities, approaches and salvage procedures have been published since that time [8].

In 1908, Cotton suggested that an open reduction of a calcaneal fracture was contraindicated and favoured closed manipulation using a hammer to reduce the lateral wall and re-impact the fracture. Despite his initial enthusiasm for this technique, by the 1920s he had given up the treatment of acute fractures altogether and turned instead to the treatment of healed mal-unions [9].

The first documented treatment of a series of calcaneal fractures with internal fixation was by Leriche in 1922. Lenormant and other French surgeons popularized this technique, alternating between screws and bone graft for stabilization of the reduction [9].

Bohler began to advocate open reduction of calcaneal fractures based on his experience with the French methods. Despite this, forcible closed reduction with tongs and hammers, or traction followed by manual manipulation and casting, were the standard treatments of his time, because of technical problems associated with surgery. Bohler himself popularized traction in multiple planes that improves the fracture reduction [9].

3. Treatment of Intra-Articular Calcaneal Fractures

Non-operative treatment is best reserved for non-displaced (Sander's type I) fractures, severe peripheral vascular diseases, insulin-dependent diabetes, soft-tissue compromise such as blistering and massive, prolonged edema which may substantially delay operative treatment and other medical problems that contraindicate an operation.

It consists of non-weight-bearing for approximately three months and early range-of motion exercises. The foot is placed in a boot, which is locked in neutral position in order to prevent an equines contracture, and an elastic compression stocking is used to minimize dependent edema [2, 10].

Surgery should be delayed after the fracture in order to allow the soft tissue swelling to subside. This minimizes the complications related to wound breakdown and ultimately allows a better end result. A period of time ranging from 7 to 14 days, during which the foot is elevated anti-inflammatory medication is prescribed [3].

In the absence of fracture blisters, the return of normal skin wrinkling is an indication that significant swelling has resolved and operative intervention may proceed. However, the surgery should not be delayed beyond 2 weeks after injury, beyond which fracture begins to consolidate. Inferior results have been shown by authors in cases where delay in surgery exceeded 3 weeks [3].

4. Open Reduction and Internal Fixation

The operation can be performed by placing the patient in either lateral decubitus or the prone position on a translucent table so that fluoroscopy may be used intra-operatively. After exsanguination of the lower extremity, the tourniquet is inflated [2, 11].

The incision starts approximately 2 cm above the tip of the lateral malleolus, just lateral to the Achilles tendon. This line is continued vertically toward the plantar surface of the heel. It is connected to a line drawn at the junction of the lateral foot and the heel pad, typically when compressing the heel, a crease will appear in this region. Posteriorly, this line connects to the vertical limb.

Anteriorly, it may be curved up to follow the skin creases, ideally centering over the middle of the calcaneocuboid joint articulation, or carried straight to the base of the fifth metatarsal. Whereas the two drawn lines form a right angle, this is replaced with a gentle curve primarily to avoid apical tip necrosis [11].

The entire soft tissue envelope is elevated off the lateral aspect of the calcaneus with the flap containing the peroneal tendons, sural nerve and CFL. It allows visualization of the entire lateral wall of the calcaneus and the posterior facet of the subtalar joint. Kirschner wires are placed as retractors in the fibula, the talar neck and the cuboid bone to maintain the no-touch technique of flap retraction [12].

The posterior facet is reduced. The reduction is checked by fluoroscopy, Then, lag screws are placed from the lateral cortex toward the sustentaculum. A low-profile lateral plate is applied to stabilize the posterior facet, the anterior process and the posterior tuberosity [13].

The extensive nature of this approach bears the risks of problems with skin healing. It worsens the traumatic devascularization of the central and anterior part of the lateral wall, as 45% of the calcaneal vascularity is derived from vessels entering at this site [14–15].

A straight 8 to 10 cm incision is made over the medial heel parallel to the sole, about halfway between the medial malleolus and the bottom of the foot. The fascia is divided in the line of the skin incision. The neurovascular bundle is dissected free, then drawn aside, revealing the sustentacular fragment below. The sustentacular spike overrides the tuberosity fragment which is displaced laterally, forward and upward. [16]

A blunt elevator is used between the spike and the tuberosity fragment and passed to the lateral side. The joint depression-type or tongue-type fragment is elevated, and the posterior facet is reduced indirectly. The tuberosity fragment is reduced to the sustentacular fragment. If the fragments are not reduced fully from the medial side, a lateral incision can be made. The reduction is maintained by the use of a staple or pin or screw drilled through the tuberosity fragment, then into the thickest part of the sustentacular fragment [16].

If the pin or screw is used alone, the need for exposure of the neurovascular bundle in the medial incision is eliminated. Burdeaux pointed out that the difficulty of reduction increased with the degree of comminution. The medial reduction technique requires a stable sustentacular fragment to which an intact tuberosity fragment is reduced [16].

Compared to the lateral approach, the medial approach provides accurate reduction of the medial wall and better bone quality for fixation but with blind reduction of the posterior facet joint and manual compression of the lateral wall of the calcaneus.

Also there is a greater potential for injury to the neurovascular bundle with the medial approach than the lateral approach. On the other hand, the lateral approach allows direct visualization of the lateral wall and the posterior facet joint and more room for fixation, but the possibility of residual hindfoot varus also exists because of the inability to reduce the medial wall [17].

5. Minimally Invasive Approaches

The primary indications for using less invasive approaches for the surgical treatment of calcaneus fractures include displaced Essex-Lopresti fractures, Sander's type II fractures, Sander's 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 [18].

A critical aspect of less invasive techniques is surgical timing. It has been 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. It is preferred 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 [18].

6. Percutaneous Treatment

- Applicable to all types of displaced intraarticular calcaneal fractures, also to severely comminuted fractures.
- Additional damage of soft tissues is avoided; only small stab-wound incisions are necessary.
- Applicable in patients with compromised soft tissues and/or comorbidity like diabetes.
- Distraction pins are not left in place lowering the risk of infectious complications.
- Shorter learning curve in comparison to ORIF [5].
- Indirect reduction of subtalar joint with the image intensifier may not result in an exact anatomic reduction.
- Percutaneous screw fixation is less rigid than plate osteosynthesis. Slight flattening of Bohler's angle may occur postoperatively.
- All displaced intraarticular calcaneal fractures, Sander's type II–IV.
- Centrally depressed fractures are not manageable by traction alone.
- Patients who are expected to be noncompliant.
- Fractures older than 7 days, because of progressive stiffening of the soft tissues, the capsule and ligaments in particular [5].
- On average < 10% wound complications, with usually a mild presentation.
- Small percentage (10–15%) of neurapraxia, lateral dorsal cutaneous nerve (continuation of the sural nerve), with temporary numbness on the lateral side of the foot.
- Non-weight bearing for 12 weeks.
- Intensive physiotherapy.
- Recovery time after surgery may be up to 1 year.
- Chance of osteoarthritis with persistent pain at rest and during walking, with indication for secondary arthrodesis in 10–15%[5].
- Two orthogonally placed fluoroscopes (axial and sagittal).
- Three 3-mm Kirschner wires, 15–20 cm in length.
- Two or three threaded guidewires and 6.5-mm cannulated cancellous bone screws [5].

The patient should be positioned correctly to obtain excellent fluoroscopic views, which are the keys to the procedure. The lateral position on radiolucent operating table facilitates acquisition of optimal fluoroscopic images from the c-arm.

The well leg is down and anterior relative to the leg requiring the operation; the leg requiring the operation is positioned flat on firm bumps to support a perfect lateral position of the foot. The surgeon stands posterior to the patient, which facilitates fracture reduction and placement of screws [4].

Obtaining excellent fluoroscopic views is an important part of the procedure, and the c-arm/leg/table orientations that optimize these views are confirmed prior to surgical preparation and draping. Position the c- arm at the foot of the operating table and at approximately a 45° angle.

- Lateral view: A lateral image of the foot is readily obtained with the c-arm in the vertical position (-a).

- The lateral oblique view: Obtain this image by rolling the c-arm back approximately 30° and canting it slightly toward the foot of the bed (-c). Various amounts of rotation and canting provide different views of the posterior facet of the subtalar joint.
- Axial view: The 45° angle of the c-arm at the foot of the bed facilitates the Harris view of the calcaneus, which is obtained by rotating the c-arm underneath the corner of the table and dorsiflexing the foot (-b) [19].

Moving the c-arm allows these views to be obtained without manipulating the foot and leg, which is important when fragments are being provisionally held in reduced positions.

- The first step in the procedure is reduction of the tuberosity as the facet will not reduce until the tuberosity is moved out of an obstructing position. Manipulate the tuberosity fragment using a large Schanz pin placed from lateral to medial in the tuberosity. The starting point should be posterior in the tuberosity and midway from top to bottom. A Harris view shows the depth of insertion.
- Use the Schanz to move the tuberosity to gain length, achieve inferior and medial translation, and correct varus as judged on the lateral and Harris views. Apply manual traction on a laparotomy sponge around the base of the corkscrew while the surgeon stabilizes it from the top to facilitate longitudinal and inferior distraction of the tuberosity while the ankle is held in plantar flexion [4–5, 19].
- Once the tuberosity is reduced, as judged on both the Harris and the lateral c-arm views, achieve temporary fixation from the posterolateral aspect of the tuberosity into the medial sustentaculum with 1.6-mm Kirschner wires.
- Place the wires somewhat medial as seen on the Harris view to avoid blocking subsequent reduction of the facet fragment(s). Assess the paths of these wires carefully on the fluoroscopic views.
- Assess the position and reduction of the articular facet fragment(s) on the lateral and Broden's fluoroscopic views, which best profile the subtalar joint.
- Reduce the fragment with a small instrument inserted through a stab incision directly under the rotated facet fragment. If the tuberosity has been correctly repositioned, the facet fragment(s) should fit well beneath the talar articular surface and the intact sustentaculum medially.
- Once the reduction of the fragment(s) is optimized, perform temporary fixation with 0.45-mm Kirschner wire(s) placed from lateral to medial beginning just posterior and inferior to the fibula from the reduced facet fragment into the sustentaculum. These wires typically incline slightly inferiorly and anteriorly from straight medial to lateral, and their position is assessed on lateral oblique views of the subtalar joint [4, 19].
- Identify screw entry points and paths using fluoroscopic images, and confirm the final positions with C-arm imaging. After the fracture is seen to be reduced on the three views of C- arm, internal fixation of the fracture with percutaneously placed 3.5 and 4.0-mm screws.
- Fixation of the facet fragment, usually by first using two 4.0 mm partially threaded screws. The tactile feedback of the 2.5-mm drill, particularly on entry into the sustentaculum, is an important part of ensuring good screw purchase on the medial side.
- The typical lengths of these screws are 35 to 45 mm. Place them under the joint laterally through the facet fragment and into the sustentaculum. Use the lateral fluoroscopic image to identify the screw entry point, the lateral oblique view to direct the screw toward the sustentaculum, and the Harris view to assess screw length [4, 19].
- Fix the tuberosity fragment to sustentacular part. Starting posterolaterally in the tuberosity and incline them medially as seen on the Harris view and often slightly superiorly as seen on the lateral view.
- Fix the tuberosity fragment to anterior process of the calcaneus. It is important to assess the path of these screws on the fluoroscopic views, but determine the length of the screws on the lateral view.
- The screws should solidly be placed flush with the back of the tuberosity to avoid prominent screw heads when swelling subsides.

- Obtain additional fixation with two or three inferiorly directed 4.0- mm cancellous screws placed from the tongue fragment and proceeding inferiorly into the posterior aspect of the tuberosity.
- The final screws length and positions should be confirmed with c- arm imaging [4, 19].

7. Arthroscopically Assisted Reduction

"Arthroscopy" appears to be superior to fluoroscopic Broden's views with respect to the resolution of the images and is less time consuming than intra-operative Broden's views with standard radiographs. Arthroscopic control of reduction of intra-articular calcaneus fractures aims at detecting remaining incongruities in the parts of the subtalar joint that cannot be seen directly. Subtalar arthroscopy "percutaneous, arthroscopically assisted osteosynthesis" adds a valuable new tool to the treatment options of intraarticular calcaneus fractures while adhering to the accepted treatment guidelines of these injuries to ensure anatomical reduction with minimally invasive manipulation of the fragments for selected fracture patterns [20–22].

Patients are placed in a lateral decubitus position with a tourniquet placed around the thigh.

- The reduction technique is the same as described before with the use of intraoperative imaging using c-arm [20].
- A small-diameter ankle arthroscope (2.7 mm, 30) is introduced into the subtalar joint via the standard anterolateral or posterolateral portal and sometimes an additional middle portal from lateral depending on the fracture anatomy.
- After irrigation, the joint and fracture are cleared of loose fragments or clots D, E & F). If residual step-offs are detected arthroscopically, fine corrections were carried out under direct vision.
- The amount of correction of the overall anatomic shape of the calcaneus is checked fluoroscopically. The fragments are fixed with 3.5- or 4.5-mm screws introduced percutaneously via stab incisions under fluoroscopic guidance (h) [23].

Generally, one or two screws are introduced parallel to the posterior facet into the sustentacular fragment, engaging the medial cortex. Fixation of the tuberosity fragment to the anterior process fragment was carried out according to the individual fracture pattern. Anatomic reduction and screw position are checked intraoperatively with Broden's views (I), lateral, and axial (H & J) radiographs [20–23].

8. External Fixator-Assisted Reduction

One of the earliest descriptions of minimally invasive treatment of calcaneal fractures through ligamentotaxis was by Clark in 1855, who described a pulley system to realign the arch of the foot. Restoring calcaneal anatomy by distraction was further developed by Böhler in the late 1920s [24].

The subtalar joint is surrounded by a strong joint capsule and numerous ligaments, which stabilize the subtalar and ankle joint. The ligaments used in ligamentotaxis between the ankle joint, talus, and calcaneus are the calcaneofibular, the tibiocalcaneal ligament of the deltoid ligament, the talocalcaneal interosseous ligament, cervical and the anterior, lateral, posterior, and medial talocalcaneal ligaments [5].

The plantar and dorsal calcaneonavicular ligament and the calcaneo-navicular portion of the bifurcate ligament are situated between the calcaneus and the navicular bone. The cuboid and calcaneus are connected by the dorsal calcaneocuboid ligament, the short and long plantar ligament, and the calcaneocuboid portion of the bifurcate ligament. Ligamentotaxis, the indirect reposition of displaced osseous fragments through distraction on the ligaments attached to these fragments, restores the height of the posterior talocalcaneal joint and reduces the varus/valgus malalignment as well as the width of the calcaneal tuberosity. The lateral joint-fragment usually remains depressed, because the fracture lines run laterally to the interosseous ligament. This fragment needs to be lifted upwards using Kirschner-wire leveraging or a bone-punch inserted plantarly via the primary fracture line to restore the joint congruence [5].

In the early decades of the twentieth century the distraction methods were applied and were the most widely accepted treatment for displaced intra-articular calcaneal fractures. The different distraction techniques can be divided into single, two-and three-point distraction, according to the number of inserted pins at points of skeletal distraction [25].

The technique began with the insertion of one Schanz screw medially into the distal part of the tibia and another into the calcaneal tuberosity.

Varus-valgus deformity could be reduced by the correct placement of the Schanz screw perpendicular to the calcaneal tuberosity. An external fixation frame was then applied over the Schanz screws and, under fluoroscopic guidance, distraction was applied in the line of the fixator bar.

With use of slow distraction between the pins, the calcaneal height, length and width were restored according to the principle of ligamentotaxis of the fracture fragments. Sufficient distraction was applied so that widening of the subtalar joint could be observed. Reduction of the articular surface is done either percutaneously or through small lateral incision [26].

Under fluoroscopy, Schanz pins were placed into the posterior inferior calcaneus, the talar neck or the cuneiforms, and the distal anterior tibia. All pins were positioned to avoid neurovascular structures. The tibial pin was placed above the tibial plafond just posterior to the anterior tibial crest. The calcaneal pin was placed into the posterior inferior aspect of the calcaneus proximal the plantar tubercles. Finally, the 3rd pin; talar pin was placed centrally through the neck of the talus or through the medial to the middle cuneiforms.

All pins were placed parallel to each other in the frontal plane and perpendicular to the long axis of their respective bone in the sagittal plane (-a). The pins were then connected together by carbon fibre rods with pin to rod adapters. Next, the construct was distracted medially and laterally between the tibial and calcaneal pins, then between the talar and calcaneal pins to restore calcaneal width, height, and length (-c,d&e). Axial and lateral fluoroscopy was used to ensure appropriate distraction, at which time the rods were locked in the distracted position.

Axial fluoroscopy was used to demonstrate reduction of varus or valgus deformity and to assess reduction of the lateral calcaneal wall. Manual compression was applied to the distracted lateral calcaneus to further reduce deformity where indicated. Broden’s views were then obtained to ensure distraction of the subtalar joint. Finally, the tibial-talar rods were adjusted to position the foot perpendicular to the leg. After final adjustments, the clamps were tightened, additional attempts at open or percutaneous reduction of the posterior facet can be added and fixation by percutaneous screws [27–28].

Several concerns regarding the effectiveness of distraction techniques have been reported, these include poor results in general, non- anatomical reduction, infectious complications, and loss of reduction [5].

No universal treatment or surgical approach exists that can be applied to treat all fractures of the calcaneus. The question remains whether adequate reduction of displaced intra-articular calcaneal fractures is even possible by closed methods. Assessing the reduction on plain radiographs, by measuring the tuber-joint angle by Bohler, does not ensure a proper restoration of the posterior talocalcaneal facet. As the percutaneous reduction of fractures is indirect, perfect anatomical restoration of the posterior facet anatomy and longitudinal arch of the foot should not be expected. These effects might be amplified by the decrease in viability of the cartilage [5].

The minimally invasive techniques were developed to protect the soft-tissues, but infectious complications do occur in patients treated percutaneously. The later distraction techniques use screws situated subcutaneously rather than transosseous pins, which has resulted in a lower complication rate [5].

Percutaneously placed screws might provide a less rigid fixation of fracture fragments compared with plating, as collapse or loss of the obtained reduction has been reported after percutaneous reduction and subsequent fixation. One study showed a similar strength of plating versus percutaneous screw fixation in Sander's type 2B fractures [5].

9. Sinus Tarsi Approach

- Applicable to all types of displaced intraarticular calcaneal fractures, also to severely comminuted fractures.
- Additional damage of soft tissues is avoided; only small stab- wound incisions are necessary.
- Applicable in patients with compromised soft tissues and/or comorbidity like diabetes [5].
- On average < 10% wound complications, with usually a mild presentation.

- Small percentage (10–15%) of neurapraxia, lateral dorsal cutaneous nerve (continuation of the sural nerve), with temporary numbness on the lateral side of the foot.
- Non-weight bearing for 12 weeks.
- Intensive physiotherapy.
- Recovery time after surgery may be up to 1 year.
- Chance of osteoarthritis with persistent pain at rest and during walking, with indication for secondary arthrodesis in 10–15% [5].

The patient is placed in a lateral position and large C-arm is used for fluoroscopy. A thigh tourniquet is also utilized.

A 4 to 6 cm incision is made extending from the anterior aspect of tip of the fibula toward the fourth metatarsal base. The sural nerve is typically not encountered, but careful dissection is recommended down to the fascia. The fascia is incised, and the underlying muscle (extensor digitorum brevis) is split and retracted. It is extremely helpful to place a bump under the ankle and let the heel joint fall into varus to facilitate exposure of the subtalar joint [29–30].

Soft tissue is carefully elevated off the lateral aspect of the calcaneus, and the split depressed fragment of the posterior facet is typically easily visualized. If the tuberosity is shortened and in varus, a Schantz pin can be placed from lateral to medial in the tuberosity and manipulated to assist the reduction. The posterior facet fragment(s) is then disimpacted and elevated with a freer elevator or small osteotome.

A large K-wire can also be placed percutaneously from posterior to anterior into the lateral posterior facet to joystick the fragment into a reduced position. The posterior facet is then reduced to the intact medial aspect of the joint, and to the anterior process at the angle of Gissane, and provisionally secured with small K-wires [29–30].

After reducing the posterior facet, as confirmed radiographically and by direct visualization, an axial heel view is obtained to ensure that the tuberosity has been neutralized. A fully threaded 6.5- or7.3-mm cannulated screw is then placed percutaneously from the posterior aspect of the heel anteriorly into the constant sustentaculum fragment.

Lastly, a small fragment plate (2.7 mm) is then placed through the sinus tarsi incision, bridging from the superior tuberosity to the anterior process of the calcaneus. This is secured with 4 to 6 screws, which can be placed percutaneously if necessary.Alternatively, the posterior facet fragment may be fixed with a subchondral lag screw and positional screw from below. Allograft can be placed into any defects but is rarely necessary [30].

10. Complications

The most common complication following operative treatment of a calcaneal fracture is wound dehiscence and infection, and this may occur in up to 25% of cases [31]. Risk factors for wound dehiscence and wound complications in general include smoking, diabetes, open fractures, high body mass index, and a single layered closure [32].

In the event of a wound dehiscence, all range-of-motion exercises should be stopped so as to prevent further dehiscence, and a course of oral antibiotics is prescribed. The limb may be placed in a cast with a window over the wound, and repeated dressing or other granulation- promoting wound agents are started on a daily basis [33].

This regimen is usually successful, as long as the wound is limited to a partial-thickness necrosis of the skin. Once the wound is healed, range- of-motion exercises are reinstituted. If all treatment methods have failed, a fascio-cutaneous flap may be needed. If gross purulence is developed, hospitalization with serial surgical debridement and the administration of culture-specific antibiotics must be started [33].

If the infection is relatively superficial, the implants should be retained, at least until the fracture has healed. After the wound bed is determined to be clean, a delayed closure, or the use of a vacuum-assisted device, is attempted if possible. If the wound is too large, a free tissue transfer is performed. Culture-specific intravenous antibiotics are administered for a minimum of 6 weeks [33].

In the event of diffuse osteomyelitis, all implants must be removed along with all necrotic and infected bone. In this case, an antibiotic impregnated spacer should be placed in the wound. Following repeated debridement and 6 weeks of culture-specific antibiotics, if the defect is clean, a subtalar fusion using a large structural iliac crest autograft can be performed, based on the amount of remaining calcaneal bone stock. In very rare instances, this will not be possible and an amputation will be required, but this is the exceptional situation [33].

One of the goals of internal fixation is an anatomical reconstruction of the joint surface of the posterior facet. The joint will deteriorate rapidly, and severe pain and disability will certainly result, if the reduction is inadequate or if the articular cartilage has been extensively damaged at the time of the injury. Even in patients who have a truly anatomical reduction, arthritis of the subtalar joint may develop as a result of damage to the cartilage at the time of the injury [2].

If post-traumatic arthritis is present clinically and radiographically, it should be verified as the cause of the pain. This can be accomplished by injecting a local anesthetic into the subtalar joint. If the pain is relieved, then non-operative measures, such as modifications of shoe wear, walking aids, and non-steroidal anti-inflammatory agents, can be tried. If these measures fail, the hardware should be removed and an in situ subtalar arthrodesis with use of bone graft and large cannulated lag screws should be performed [2].

This problem is generally seen following nonoperative treatment because of lateral impingement, where the displaced, expanded lateral wall sublaxes the peroneal tendons against the distal tip of the fibula or dislocates the tendons. Entrapment may also occur after operative treatment [34].

Patients may also develop adhesions and scarring of the tendons either from the surgical approach or from prominent adjacent implants. Nonoperative management includes non-steroidal anti-inflammatory medication and physical therapy for manual mobilization, stretching and eversion strengthening. If these modalities fail to provide relief, a peroneal tenolysis and/or removal of the symptomatic implants may be necessary [33].

The most common neural problem associated with operative treatment is damage to a sensory cutaneous nerve. The sural nerve is most commonly injured because of the frequency of use of the lateral approaches, however: nerve injury also may occur after a medial approach, with the calcaneal branch of the posterior tibial nerve most commonly affected. A neuroma or complete loss of sensation in the affected region may develop. Non-operative treatment is advised. When a neuroma is painful, resection with burial of the stump into deep tissue is recommended [2].

Entrapment or compression of the posterior tibial nerve, more commonly seen after non-operative treatment, can occurs secondary to a malunited fracture [35]. Patients report pain in the medial aspect of the heel and paresthesias in the distribution of the posterior tibial nerve. The pain is frequently worse at night or with walking or standing. A trial injection of a local anesthetic into the tarsal tunnel can assist in making the diagnosis. If the diagnosis remains in doubt, electro-diagnostic studies are indicated. When clinical and diagnostic tests show nerve entrapment, operative decompression of the posterior tibial nerve and its branches may provide relief [2].

Reflex sympathetic dystrophy may occur regardless of the method of treatment and may result in long term and possibly permanent functional impairment. The clinical diagnosis is made when the patient has pain that is disproportionate to the extent of the injury, cold and clammy skin, purplish discoloration, an inability to tolerate anyone touching the foot and difficulty wearing shoes. Myerson and Quill confirmed the diagnosis when a tibial nerve block did not relieve the symptoms. Early the symptoms may be reversed with use of intensive therapy such as massage, motion and manipulation, or weight-bearing if the fracture has healed. More resistant cases may necessitate multiple lumbar sympathetic nerve blocks [36].

Chronic pain in the heel pad may occur as a result of damage to the unique septated architecture of the heel pad. Sallick and Blum recommended sensory denervation for this problem. However, Barnard and Odegard as well as Lance et al. noted that plantar pain secondary to a damaged heel pad is not alleviated by operative treatment [2].

Subtalar motion is compromised to variable degrees after calcaneal 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 [37].

11. Clinical and Radiological Outcomes

Ibrahim Mahmoud Morsi and Hesham Hussien - in Orthopedics and Traumatology Department, Aswan Faculty of Medicine, Aswan University-made study for evaluation of the short-term results of closed reduction and percutaneous

K-wires fixation of displaced intra-articular calcaneal fractures (DIACF) nearly same our technique and they got these results, functional outcomes.

According to the AOFAS scoring system, the mean score at the final follow up was 84, and it was graded as excellent in 9 patients (45%), good in 9 (45%), and fair in 2 (10%). Subtalar joint motion of a mean 80% of the healthy side with 12 patients (60%) had an excellent range of motion with no restriction, 6 (30%) with moderate restriction, and two patients (10%) had severe restriction. Regarding pain, in six (30%) patients, there was no pain, 12 (60%) had mild (occasional) pain and 2(10%) patients had moderate (daily) pain [27].

Also the radiographic outcomes Fracture union was achieved in all patients at a mean of 8.8 ±3.1 weeks. Regarding angles measured, the Bohler's angle and Gissane's angle and improved significantly from a mean 18.7◦±(4.9) and 123.1◦±(9.9) preoperatively to a mean postoperative angle of 25.3◦± (4.8) and 120.8◦± (8.2) respectively,for the three lengths measured (in mm), height, length and width the improvement was significant from a mean preoperative of 41.9 ± (2.9), 73.7 ± (3.3) and 44.1 ± (2.8) to a mean postoperative measurement of 42.2 ± (1.4), 75.1 ± [38] and 40.9 ± (2.6) respectively.

Ayman Youssef Eltabbaa used minimally invasive technique K-wire fixation of displaced intraarticular calcaneal fractures through a minimal sinus tarsi approach and they reached the following results the mean AOFAS score was 78.4 (ranging from 55 to 95). As regard to the radiographic evaluation, the mean preoperative Bohler's angle and angle of Gissane were 12.4° and 127.9°, respectively, and the mean postoperative Bohler's angle and angle of Gissane were 26.3° and 107.3°, respectively. All patients healed within 4 months; no patients had a loss of reduction after wire removal, At the end of the study, nine patients (16%) had persistent pain. Subtalar injection relieved the pain success fully in four cases; however, subtalar fusion was needed in five cases (8.9%) due to persistent pain after injection. Infection was encountered in eight patients (14%): two cases of deep infection and six cases of superficial pin site infection. The deep infection was severe in one patient, which necessitated the removal of the wires prematurely, with fair end results. The other patient developed a deep infection a few days after the removal of the wires, as he was a farmer and he worked in his farm a few days after the removal of the pins; complete healing was achieved following surgical debridement. Superficial pin site infection was controlled with oral antibiotics. One patient (1.7%) reported numbness over the lateral aspect of the foot.[39]

Tim Alexander Walde B. Sauer J.Degreif H.-J. Walde also made a study on Closed reduction and percutaneous Kirschner wire fixation for the treatment of dislocated calcaneal fractures and they got these results as Böhler's angle was restored in 70.1% (47 of 67) of the cases, a total of 85.1% (57 of 67) cases had a reduction in calcaneal height to within 10% when compared to the non-operative side, additionally, a reduction in the length of the calcaneus occurred within 10 in 94% (63 of 67) of cases when compared to the non-operative side. Thirty-eight (56.8%) of the 67 patients had a widening of the calcaneus to within 10% compared to the opposite side.[40]

J.L. Marsh used percutaneous technique for reduction and internal fixation of displaced intra-articular calcaneal fractures and got the following results in seventy-nine patients with a total of eighty-three fractures were compared with those obtained by another surgeon using the extensile lateral approach1. There were no significant differences in the degree to which the Böhler angle was restored (p = 0.31) or in the average loss of postoperative reduction at the time of fracture union. There were significant differences in the rates of complications. None of the patients who underwent percutaneous reduction and internal fixation developed a deep infection.[41]

Deplase eklem içi made a study on Modified percutaneous fixation for displaced intra-articular calcaneal fractures in his study, the total of 18 patients were bilateral, while the number of operated calcaneal fractures was 132. Mean age was 40 years (range, 17 to 66 years) for males, 37 years (range, 16 to 58 years) for females, and 39 years (range, 16 to 66 years) overall. Forty-four patients were smokers (38.5%), while 13 were diabetics (11.4%). Three patients suffered from chronic renal failure (2.6%). Six patients were drug addicts (5.2%). Sixty patients (45.45%) had additional orthopedic injuries. The increase in the postoperative Bohler's angle measurements compared to preoperative values was statistically significant (p=0.001).

The distribution of patients with abnormal angle was none for type II, 27% for type III (21/76), and 53% for type IV (26/49). According to Sanders classification, seven feet (5.3%) were type II, 76 feet (57.57%) were type III, and 49 feet (37.12%) were type IV, mean AOFAS score was 80.4 (range, 47 to 92). According to Sanders classification, the mean AOFAS scores were 81.25 for type II, 81.88 for type III, and 80.19 for type IV.

Four feet had wound-related complication (3.02%), all resolved by appropriate treatment, six feet (4.54%) needed a second surgical procedure, five patients had subtalar arthrodesis, while one patient had lateral wall exostectomy. Mean duration of operation was 8±1.5 minutes, this duration did not show any statistical significance between various fracture types. Mean time to bone healing was 8.43 weeks (range, 7 to 12 weeks). Passive ROM started at sixth-eighth weeks. Weight bearing started at 8th - 10th weeks.[42]

12. Conclusion

Calcaneus fractures are generally quite severe injuries, and often lead to longstanding problems of the foot and ankle. Many specialists observed that different forms of treatment were associated with specific complications.

Conservative treatment, however, showed more long term complications involving arthritis, malunion and lateral impingement of the peroneal tendons which can occur as a result of calcaneal broadening.

The extended lateral L-shaped approach is commonly used for the surgical treatment of intra-articular calcaneal fractures, this approach accurately reduces the subtalar joint, fully exposes, and addresses the intra-articular calcaneal fragments and conveniently places the plate to achieve a stable fixation. Wound dehiscence is the most common problem after open reduction and internal fixation (ORIF) of a calcaneal fracture to be as high as 30%. Risk factors for wound dehiscence and wound complications in general include smoking, diabetes, open fractures, high body mass index, and a single layered closure, also in recent techniques including limited-incision sinus tarsi ORIF and MIPO still there are many problems as wound dehiscence, infection and need for implant extraction.

The closed reduction and percutaneous fixation via Kirschner wire for treating displaced intra-articular calcaneus fractures have been undertaken in an attempt to reduce complications and improve recovery when surgery is indicated.

The early results reported reduced complication rates and promising clinical and radiographic outcomes in certain fracture patterns and patient populations, it is a promising solution for selected cases who have risk factors for wound dehiscence and wound complications in general include smoking, diabetes, open fractures, high body mass index, and a single layered closure.

This emerging technique may be beneficial in patients with soft-tissue compromise, multiple comorbidities, and displaced intraarticular fractures with minimal commination.

In conclusion, the closed reduction and percutaneous Kirschner wire fixation technique is effective methods for adequate reduction and restoration of all parameters of calcaneus (height, length, width, heel varus and alignment of the posterior facet) allowing rigid fixation in minimal operative timing with minimal postoperative complications.

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