Displaced Intra-articular Calcaneal Fractures: Current Concepts and Modern Management

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ABSTRACT

The calcaneal fractures are usually the result of high-energy injuries, falls from height and road traffic accidents and constitutes about 2% of all fractures. 60 to 75% of them are displaced intra-articular fractures and 90% of them are usually in males, mainly in industrial workers. there is still controversy regarding classification and treatment. The purpose of this review is to present the modern surgical modalities for these type of fractures.

Keywords: Calcaneus, Calcaneal fractures, Foot, Fractures, High energy fractures, Ilizarov, ORIF.

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INTRODUCTION

The calcaneal fractures are usually the result of high-energy injuries, falls from height and road traffic accidents and constitutes about 2% of all fractures.¹ 60 to 75% of them are displaced intra-articular fractures and 90% of them are usually in males, mainly in industrial workers. Ten percent have associated fractures of the spine and 25% have other extremity injuries. The economic impact following calcaneal fractures is huge since about 20% of the patients are totally incapacitated for 3 to 5 years.¹⁻³ Functional results of displaced intra-articular fractures are not optimal and there is still controversy regarding classification and treatment.⁴ The purpose of this review is to present the modern surgical modalities for these type of fractures.

ANATOMY AND RADIOLOGY OF CALCANEAL FRACTURES

The calcaneus is the largest of the tarsal bones. It is cuboidal in shape and its long axis is directed forward, upward and laterally. The superior surface consists of three articular facets with the talus: the posterior (the major weight bearing and the largest of the three), the medial or the sustentaculum tali (located on a shelf-like process) and the anterior, the calcaneus articulation with the cuboid.

The evaluation of calcaneal fracture should start with simple radiographs. There are five different views to assess calcaneal fracture: the lateral (Fig. 1) and the Broden view (the foot is in neutral position, the leg is in internal rotation of 30°, the beam is over the lateral malleolus and X-rays are taken in 40, 30, 20 and 10° toward the head of the patient) to assess any incongruity, compression or rotation of the posterior facet;⁵ the axial or the Harris view to assess any deformation or widening of the tuberosity; and the oblique and anterior-posterior views to assess the anterior process of the calcaneus and the calcaneocuboid joint.⁶

CLASSIFICATION OF CALCANEAL FRACTURES

Two types of calcaneal fracture may occur, extra-articular and intra-articular.

The Essex-Lopresti classification is based on the mechanism of injury and cannot predict clinical outcome

Fig. 1: Plain radiographs of a 35-year-old male who fell from a roof of 4 meters high with comminuted fracture of his left calcaneus. The Bohler's angle in the right side is 28° whereas in the left side it decreased to 4°. The Gissane's angle in the right side is 95° and in the left deformed calcaneus 35°

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and is divided to type A-Joint depression fracture, and type B-Tongue type fracture. The displaced articular surface fracture results in a tongue or joint-depression fragment. Essex-Lopresti suggested that tongue-type fractures will be reduced by percutaneous leverage and joint-depression fractures will be reduced by open reduction and internal fixation.⁷

The most common classification of calcaneal articular fracture used nowadays was described by Sanders.⁴ The Sanders' classification is based on the coronal projection of the posterior facet and the sustentaculum tali, and on the number and the location of the fragments (Fig. 2).

MODERN TREATMENT MODALITIES OF CALCANEAL INTRA-ARTICULAR FRACTURES

Until 20 years ago calcaneal intra-articular fractures were treated mostly nonoperatively. The introduction of CT scans has contributed to the understanding of mechanism of the fracture with its evaluation and classification, leading

to development of new surgical techniques and development of anatomical devices for internal fixation as follows:

Open Reduction and Internal Fixation of Displaced Intra-articular Calcaneal Fractures

The classical surgical approach is the lateral one. The patient is placed in a lateral or prone position and a tourniquet is used. The calcaneus is approached through an 'L'-shaped incision: the perpendicular incision is located anterior to the Achilles tendon sparing the sural nerve, while the horizontal incision runs along the plantar hematoma line and curves up distally to the calcaneocuboid joint (Fig. 3). A full thickness flap is then elevated through the periosteum to prevent damage to the peroneal tendon and the sural nerve (Fig. 3A). Following exposure of the subtalar and calcaneocuboid joints two Kirschner wires (KW) of 2 mm. size are inserted in the talus and one K wire in the cuboid, and bent upward to be used as retractors. The lateral wall of the fracture is reflected or removed. Bone debris, blood clots and

Fig. 2: An illustration of Sanders' classification of fractures of calcaneus based on CT findings of number and location of fracture fragments as explained in the manuscript (printed with permission of Prof Roy Sanders²⁹)

synovial tissue are excised. The articular fragments are reduced (Fig. 3B) and fixed by KW that is pointed to the sustentaculum tali (inferior to the tip of medial malleolus), guided by fluoroscope, and then by cannulated half threaded 3.2 mm screws. The use of supplementary bone graft (Fig. 3C) is controversial as it is bone loss dependent and usually unnecessary.⁸⁻¹⁷ Correction of the compression and varus deformity of the calcaneal body is done by a 6.5 mm threaded pin that is inserted in the posterior inferior calcaneal body.

Once the reduction is achieved a buttressing calcaneal plate is inserted under fluoroscopy (Figs 3D and E). It is very important to reduce the lateral wall and avoid any metal protrusion to prevent lateral impingement with the lateral malleolus (Figs 4A to E and Fig. 5).

Postoperative Care

The patient is instructed to prop his leg up on a pillow and to engage in nonweight bearing ambulation. He may

Figs 3A to E: The stages of the operation as follows: The incisional line is in a form of L-shape demonstration the tip of lateral malleolus, direction of peronei tendon and exploration of the sural nerve (A) followed by open reduction and anatomical alignment of the bony fragments (B) augmentation of synthetic bone graft and fixation by calcaneal plate (C to E)

Figs 4A to E: A 54-year-old male with a comminuted fracture of his left calcaneus, grade IIA (A to C) treated by open reduction and fixation by calcaneal plate (D and E)

Figs 5A and B: A 52-year-old male with severe comminuted fracture of his left calcaneus, grade IV treated by open reduction and fixation by calcaneal plate with initial subtalar fusion

be discharged from the hospital on the third postoperative day, after the wound has been observed for any edge necrosis or dehiscence, that is relatively common, and after a shortleg, nonweight bearing soft cast in neutral position has been applied for the next 3 to 4 weeks. When the cast and the stitches are eventually removed, a removable boot is applied for another 4 weeks, and the patient is instructed to begin gentle passive and active motion. About 8 to 10 weeks postoperatively, X-rays are taken for bone healing verification and if healing has progressed as expected, progressive weight bearing is allowed with physiotherapy to recover the range motion of the ankle, subtalar

and foot joints. About 3 to 6 months postoperatively, the patient is allowed to walk with normal shoes. Patients who have subtalar fusion receive the same postoperative care, except for the subtalar motion.

Results of Surgical Treatment

Both Crosby and Fitzgibbons¹⁸ and Kitaoka et al^{19,20} have shown poor clinical results in patients treated nonoperatively in displaced articular fractures and recommended operative treatment. The lateral approach is used by most surgeons since it enables open reduction of displaced articular and body fracture.

Figs 6A to D: CT of a 29-year-old male who fell from a building of 5 m height suffering from comminuted intra-articular fracture of both calcanei. The patient was treated by closed reduction and fixation by Ilizarov frames of both lower limbs, including foot support for full weight bearing for 2 months

Sanders observed that the clinical results are a surgeon-dependent learning curve and requires 35 to 50 cases or about 2 years' experience.^{2,4} His radiographic and clinical outcome was based on CT follow-up and the Maryland foot score. Sanders achieved a good reduction of heel height, length, width and Böhler's and Gissane's angle that were almost normal regardless of fracture type. With type II fractures, 86% had radiographic anatomic reduction of the articular surface, 73% had good or excellent clinical outcome. In the remainder, 10% had fair clinical outcome and 17% were considered failures in which 50% of these required subtalar fusion. With type III fractures, 60% had radiographic anatomic reduction of the articular surface, 70% had good or excellent clinical outcome. As for the remainder, 10% had fair clinical outcome and 20% were considered failures in which 78% of these required subtalar fusion. With type IV fractures, no anatomic reduction was achieved, 27% had radiographic near anatomic reduction of the articular surface, 18% had approximate reduction of the articular surface, 18% had no reduction of the articular surface, 9% had good or excellent clinical outcome, 18% had fair clinical outcome and 73% were considered complete failures.

Sanders et al concluded that anatomical articular reduction is mandatory to obtain excellent or good results. However, anatomical articular reduction cannot ensure good or excellent clinical results, probably because of injury to the cartilage at the time of impact. In their opinion reproducible operative technique is surgeon-dependent. It was also suggested that type IV fractures are so severe that a primary arthrodesis is indicated after reconstruction of the calcaneal shape and that the results deteriorate over time as the number of articular fracture fragments increases.^{2,4} Similar results were also described by other authors.²¹⁻²⁷

Complications

Injury to the sural nerve may occur using lateral approach, while injury to the calcaneal branch of the posterior tibial nerve may occur using medial approach. The damage can cause neuroma or loss of sensation in the affected region. Nerve entrapment of the posterior tibial nerve can occur secondary to fracture malunion.²¹ The incidence of wound dehiscence and apical necrosis is 10 to 13% and osteomyelitis is 1.3 to 2.5% in patients who undergo surgery.^{22,28} Other complications include arthritis of the subtalar and the

Figs 7A to F: Postoperative radiographs and clinical appearance of the same patient, 6 months after injuries and 4 months after removal of Ilizarov's frames demonstrating fracture healing and almost normal bone alignment and calcaneal reconstruction of both calcanei, with anatomical shape of foot. He had a full ROM and could stand on heels and toes

calcaneo-cuboid joint,²⁸ malposition due to varus deformation of the tuberosity,² tendinitis or dislocation of the peroneal tendon caused by lateral impingement,² heel pain due to the crush injury to the soft tissue,² malunion of fractures that cause pain and disability are treated by osteotomies,² heel exostosis at the plantar aspect of the heel² and complex regional pain syndrome.²¹

Treatment of Calcaneal Fractures by the Ilizarov External Fixation Method

The Ilizarov External fixation method for intra-articular calcaneal fractures is based on closed reduction and percutaneous fixation with a Ring Frame. It is a simple, easy and reliable method, with a very low complication rate and with comparable results with other methods of treatment. The principal of fracture reduction into the frame consists of ligamentotaxis. The frame fixation allows the orthopedist to achieve stable fixation after reduction with more precise reduction including small fragments. It allows immediate mobilization of the patient the day after surgery with possibility for weight bearing depending upon how much pain the patient will tolerate (Figs 6 and 7A to F).

All procedures are done under C-arm X-ray. Fixation of proximal ring or 5/8 half ring is done by 1 wire and 2 half pins, followed by provisional fixation of calcaneus to foot frame with a single transverse KW passed through tuber

calcanei as distal as possible. In some cases with severe comminution, even subperiosteal placement of provisional wire may be acceptable. Afterwards, fixation of metatarsal bones to foot frame is performed by additional transverse KW. It is important to fix those transverse pins with the foot frame during their bending in a bow like shape. The concave side of the calcaneal pin should be toward the tuber calcanei, and the concave side of the metatarsal pin should be toward the toes. The tensioning of these two pins applies longitudinal fraction of the foot and restoration of the initial length of the foot by ligamentotaxis. The next step consists of reduction of the Bohler Angle by distraction between foot frame and base; this will pull the calcaneus downward. At this stage manual reduction may be added by squeezing of calcaneus and its reshaping. During those manipulations, the subtalar joint will be opened by distraction approximately 7 to 10 mm. In cases of displaced fractures and depression of bone fragments it is possible after initial reduction by ligamentotaxis, to elevate the depressed upper surface of bone, using a curved bone punch which is inserted from the lateral side into the calcaneal bone through a small incision. Additional fixation is performed by KW through the upper anterior, almost subarticular part of the calcaneus. If on a preoperative CT scan considerable widening of calcaneus is noted, we used 'olive wires' with stoppers in order to decrease this deformity. When the desired reduction is

Figs 8A to D: A 49-year-old male with a 'tongue' like fracture of the calcaneus and minimal displacement of the posterior facet of the right calcaneus, treated by closed reduction and percutaneous fixation by cannulated screws

achieved, final stabilization of calcaneal bone is performed by two or three oblique cross wires through the calcaneal body and through the tuber calcanei. If after elevation of depressed upper bone surface, a large cavity appears, then percutaneous intraosseous injection of bone substitute is done, using calcium pyrophosphate

After completion of frame stabilization, additional treaded rods are inserted between the anterior arch of the foot frame to the base. Sterile dressing with synthomycin ointment is applied around the pins and wires for 2 days. After two days, all bandages are removed and the area is cleaned twice daily with a spray of 70% alcohol. Patients are allowed to shower and clean the skin around the pins and wires with polydine scrub. The same treatment is maintained until frame removal. Physical therapy is started on the day after surgery. If the patient's condition (according to presence of polytrauma) allows weight bearing, partial weight bearing is started to the pain-tolerance point and increased gradually. In order to achieve immediate mobilization of patients with bilateral calcaneal fractures we add an additional ring below the foot frame; this allows easier weight bearing without direct contact between floor and heel.

Leonard et al described the use of skeletal traction through calcaneus prior and during application of external fixation.²⁹ We found this unnecessary, since adequate reduction may be achieved easily by provisional KW which connected to the most distal ring. There are instances in which ORIF, through any approach, may be contraindicated, such as severe comminution and soft-tissue compromise.²⁹ In such cases of severe comminution of subtalar joint, arthrodiastasis of this joint by Ilizarov system is very helpful, and only a few patients will need subtalar arthrodesis in future. Ilizarov EF allows the restoration of the shape of the calcaneal bone, and stable fixation of even small fragments once reduced.³⁰ This makes early weight bearing possible. Early mobilization of patients with polytrauma or bilateral calcaneal fractures changes the rehabilitation period dramatically. According to Emara et al the functional and radiographic outcomes of this technique were similar to those of ORIF.³¹ Paley and Fishgrund cited the period of prolonged nonweight bearing as a major contributing factor, during which time the soft tissues, particularly the heel pad, become overly sensitive.³² Ilizarov external fixation allows early weight bearing, and

helps to avoid oversensitivity of the heel pad as well as disuse osteoporosis of foot and ankle.

Subtalar Fusion

When open reduction of a comminuted fracture is impossible or failed, a subtalar fusion is performed using supplementary bone graft from the iliac crest in cases of major bone loss. The reduction is held in place by KW that are inserted under fluoroscopy. Two 7.3 mm cannulated half threaded cancellous screws are inserted under fluoroscopy from the posterior tuberosity into the anterior dome of the talus and the alignment is checked again under fluoroscopy (Fig. 8). The tourniquet is deflated, careful hemostasis is performed, and subcutaneous and cutaneous sutures are applied carefully to achieve perfect adaptation to avoid tension on the skin edges. A padded soft dressing is applied.⁴

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