Crush Fractures of the Anterior end of Calcaneum

Abstract

The anterior end of calcaneum fractures can present as inversion injuries, stress fractures or as a part of displaced intraarticular calcaneum fracture. Rarely, these may occur due to abduction injury from a laterally directed force that crushes the anterior calcaneum instead of the cuboid, and has associated medial column injuries which are unrecognized. Compression fractures of the anterior calcaneum are actually lateral column shortening injuries with poor outcomes in the few published reports. We describe three patients with compression fractures of the anterior end of calcaneum resulting from foot abduction injury which were managed by reduction and column length restoration via distraction by external fixator. All three fractures showed good to excellent outcomes using the American Orthopedic Foot and Ankle Society midfoot score at followup >1 year. Awareness of this injury pattern is important, and appropriate measures to reduce and maintain the fracture reduction are needed to avoid long term disability.

Keywords: *Anterior process of calcaneum, calcaneal fracture, lateral column foot injury, midfoot abduction injury*

MeSH terms: *Tarsal joint; fracture fixation; calcaneus*

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Introduction

The calcaneum is the largest of the tarsal bones. In orthopedic terms, it is thought to comprise of five bony fragments (sustentacular fragment, tuberosity fragment, subtalar joint fragment, anterior process fragment, and anterior subtalar joint fragment) and 4 joints – posterior subtalar joint, calcaneocuboid joint, middle, and anterior facets of the anterior subtalar joint.[1]

Much of the published literature on calcaneum fractures focuses on displaced intraarticular calcaneum fractures or tuberosity fractures. The anterior end, comprising of the anterior third that articulates with the cuboid, has also been termed the anterior process (processus anterior) of the calcaneum. Here, fractures are uncommon and could be small pulloff fractures, occurring as an inversion strain and often being missed as they are small chips, or large crushing injuries, which occur due to a laterally directed abduction force, which disrupts and shortens the lateral column of the foot. The latter is a more complex injury and usually occurs as part of a more complex midfoot injury, when the dislocating midfoot crushes the anterior end of the calcaneum instead of breaking the cuboid; the whole foot is unstable in this scenario. Crush injuries involving the anterior end of the calcaneum are of a similar nature, but the medial column of the foot is seemingly intact. The lateral column nevertheless is shortened and disrupted, and the fracture involves the calcaneocuboid joint.

The literature on anterior end of the calcaneum fractures occurring due to abduction forces is sparse, and the management protocols for such injuries are ill defined. Both nonoperative and operative methods have been described, with varying outcomes.[2-5]

We present a series of three patients with fractures of the anterior end of the calcaneum, all of whom were managed by a protocol of fracture distraction and fixation. We also present a review of literature on this uncommon injury pattern.

Materials and Methods

We encountered three patients in whom the anterior end of the calcaneum was fractured; all resulted from significant high-velocity trauma between January 2013 and January 2016. These injuries were three of several complex midtarsal fractures/dislocations seen during this period. These patients were managed surgically using Joshi's external stabilizing system (JESS)

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fixator (indigenous external fixator) which was applied on the lateral aspect of the foot under fluoroscopic guidance to distract the lateral column. The reduction of anterior process of the calcaneum was then stabilized by K-wires to hold the fragments [Figure 1]. Case details, including mechanism of trauma, nature of the injury, and the clinical picture at presentation and radiographs/computed tomography (CT) scans, were reviewed. All patients were again called for review in June 2017.

The PubMed, EMBASE, and Google Scholar databases were searched using keywords "*Anterior process calcaneum, Anterior end calcaneum, complex midfoot injury, and Abduction foot injury."* Pearling of the references of full-text articles included was conducted to identify articles which were missed in the primary database search.

We included all studies reporting anterior end of the calcaneum fractures. Cases of all age groups were included, and no language barrier was applied for the search. The following data were collected – journal name and year of publication, country of origin, demographic features of the patients, duration at presentation, clinicoradiologic features, and details of management. This data were analyzed

Figure 1: (a) X-ray of foot anteroposterior view (b) Clinical photograph after fixator application showing Joshi's external stabilizing system fixator application to distract the lateral column of the foot. 2.5 mm schanz Pins/K-wires are inserted in the calcaneal tuberosity, and the 5th Metatarsal and the column length is achieved by distraction

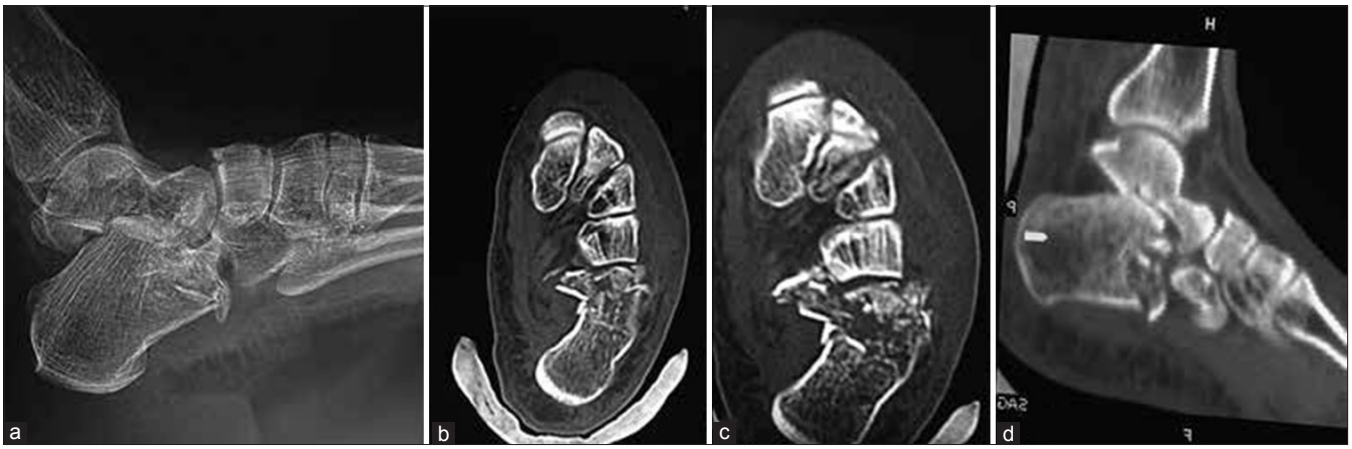

Figure 2: Preoperative X-ray ankle joint (a) and noncontrast computed tomography of the first case (b,c,d) showing comminuted fracture of the anterior end of the calcaneum with posterior facet dislocation of the talus

Table 1: A concise data review of all studies describing anterior end calcaneal fractures

Study with year and journal	Number of cases	Mechanism of trauma	Management	Associated injuries/ conditions	Outcome	Complications
Dewar and Evans, 1968 JBJS (Br)[6]	5	Forced Forefoot abduction	3 cases calcaneocuboid fusion±fixation of navicular tuberosity if fractured 2 cases: Nonoperative management	Avulsion fracture of the navicular attached to the tibialis posterior	Patients who were managed nonoperatively-pain and restricted ability to walk. Operatively managed cases: Free from symptoms and returned to full activity	Treatment by plaster immobilization alone has resulted in persistent disability
Hunt, 1970 JBJS (Br)[7]	1	Abduction injury	ORIF with K-wire	4th metatarsal fracture	1 year followuppatient can walk bearing full weight with mild pain on uneven ground	NS
Langdon *et al*., 1994, JBJS (Br)[8]	26	Associated with DIACF	ORIF	DIACF	NS	NS
Trnka *et al*., 1998 Arch Orthop Trauma Surg[4]	1	Inversion and plantar flexion	Excision of fragment using Sinus tarsi approach	NS	12 months- relief of pain	Calcaneocuboid arthrosis
Ouellette *et al*., 2006 Skeletal Radiol[5]	14	Inversion injury with the foot in plantar flexion	Nonoperative	talus (*n*=5), navicular bone (*n*=3), cuboid (*n*=2), and calcaneal body (*n*=1), ATFL tear (*n*=3) and tears of the peroneus brevis (*n*=3) and peroneus longus	NS	NS
Petrover *et al*., 2007 Skeletal Radiol[2]	15	Flexion, inversion injury and distraction of the bifurcate ligament leading to avulsion	NS	Calcaneonavicular coalition (*n*=9) thickened ATFL (*n*=6) thickened bifurcate ligament (*n*=9)	NS	NS
Hagino *et al*., 2009 Arch Orthop Trauma Surg[3]	1	Plantar flexion inversion	ORIF with K-wires	5th metatarsal fracture with midfoot dislocation	2.5 years mild midfoot pain on prolonged JSSF score 90. No arthropathic changes in calcaneocuboid joint	NS
Budd *et al*., 2010 JBJS (Br)[9]	1	RTA exact mechanism NS	ORIF using sinus tarsi approach usin HCS	Subtalar dislocation	15 months-patient can walk bearing full weight, mild pain on inclines and hard ground	Subtalar movement was minimal, and there was generalized osteopenia on plain radiographs
Pearce *et al*., 2011 Foot and Ankle Internatioanl[10]	1	Stress fracture in athlete with associated tarsal coalition	ORIF using sinus tarsi approach and calcaneonavicular bar excision	None. Associated calcaneonavicular coalition	AOFAS hindfoot score-97/100 AOS score for pain 3% and for disability 0 Total SF-36 score was 89	NS

Contd...

Table 1: Contd...

Study with year and journal	Number of cases	Mechanism of trauma	Management	Associated injuries/ conditions	Outcome	Complications
Taketomi *et al.*, 2015 Foot and ankle specialist[11]	1	Stress fracture Nonunion	Drilling of the fragment with 1.5 mm K-wires	None	6 months - Fracture union and patient was symptom-free	NS
Hui and Lui 2015 BMJ Case reports[12]	1	Forceful eversion of foot	Nonoperative (closed reduction of subtalar dislocation)	Anterior subtalar dislocation with talonavicular subluxation	12 months - Mild pain on uneven ground	None
Graham 2016 Orthopedic Nursing[13]	1	Forceful inversion of the ankle with plantar-flexion	Nonoperative	None	3 months-some return of functional activity	None

NS=Not specified, DIACF=Displaced intraarticular calcaneal fractures, ORIF=Open reduction internal fixation, AOFAS=American Orthopedic Foot and Ankle Society, AOS=Ankle Osteoarthritis Scale, ATFL=Anterior talofibular ligament, JSSF=Japanese Society of. Surgery of the Foot

qualitatively, and the results are summarized in a tabular fashion [Table 1].

Results

Case 1

A 47-year-old female sustained a foot injury while she was driving a two-wheeler and was hit by a truck; clinical examination revealed no wounds, a mild ecchymosis in the region of calcaneocuboid joint and significant tenderness over anterior end of the calcaneum. X-ray and CT scan showed a comminuted fracture of the anterior end of the calcaneum with the involvement of the calcaneocuboid joint and a subtalar dislocation [Figure 2]. Under fluoroscopic guidance, JESS fixator (indigenous external fixator) was applied on the lateral aspect of the foot to distract the lateral column. Through a small incision, lateral column length was improved with a distractor and stabilized by appropriately sized tricortical iliac crest graft, which was then fixed by K-wires to hold the fragments. The subtalar joint was reduced and fixed with K-wires. The fixator was maintained for 6 weeks following which the patient was given a walking plaster boot and encouraged to partially weight bear. Full-weight bearing was allowed after 12 weeks when the walking cast was removed. At 26 months followup, the patient had no pain, good foot alignment and has returned to her occupation; the American Orthopedic Foot and Ankle Society (AOFAS) Midfoot score was 85 (good). Weight-bearing films showed mild calcaneocuboid arthrosis due to which the patient had occasional pain on prolonged walking [Figure 3].

Case 2

A 22-year-old farmer presented with a laceration on the dorsum of the foot, after his foot had run over injury by a tractor in the fields. Radiographs revealed a comminuted fracture of the anterior end of calcaneum with midfoot subluxation, which was better defined by CT scans [Figure 4]. The patient was treated with wound debridement and JESS fixator with percutaneous K-wire fixation. The fracture fragments were reduced and fixed with K-wires, and the construct was offloaded by an external fixator [Figure 2]; the calcaneocuboid articular surface was congruent. The postoperative protocol was same as in Case 1. At 14 months, the AOFAS midfoot score was 93 (excellent). Weight-bearing films and clinical examination at last followup revealed excellent midfoot alignment and no calcaneocuboid arthroses [Figure 5].

Case 3

A 24-year-old male presented to our trauma center with a history of fall from bike with pain, swelling, and deformity over the distal leg and a degloving wound over dorsum of the foot. Radiographs showed a fracture of distal tibia and fibula (extraarticular) and an open fracture of anterior end of the calcaneum. The wound was debrided, and the fractures were fixed using hybrid fixator for distal leg fractures and distraction by JESS and K-wires for anterior end calcaneum. Skin cover was achieved using a split skin graft over the raw area [Figures 6 and 7]. At 6 weeks, the JESS fixator was removed while the hybrid fixator for leg bones was continued for another 4 weeks till the tibial fracture became sticky; subsequently PTB cast was applied till union was seen.

The patient was reassessed at 12 months; the distal leg bones fracture united and he had AOFAS midfoot score of 82 (good). His midfoot alignment was acceptable both clinically and radiologically, and the patient had resumed his occupation.

Discussion

Due to the lack of uniform terminology, the orthopedic, anatomic, and radiological literature defines the anterior end of the calcaneum differently. The anterior portion of the calcaneum is not described as a bony landmark in contemporary Anatomy textbooks. Golder in 2004 reviewed the literature explicitly and proposed that the anterior portion which articulates with cuboid should be

Figure 3: The first case with a followup of 26 months and an American Orthopedic Foot and Ankle Society score of 85. (a) Preoperative X-ray of foot showing comminuted fracture of the anterior end calcaneum with subtalar dislocation (b) noncontrast computed tomography of the foot confirming the diagnosis (c) Immediate postoperative clinical photograph showing fixator *in situ* (d) Postoperative X-ray showing adequate length restoration of lateral column with additional iliac crest bone graft (e) Clinical photograph and X-ray of foot anteroposterior view at 26 months showing good foot alignment and mild calcaneocuboid arthritis

Figure 4: Preopertive X-ray anteroposterior view and three dimensional computed tomography showing fracture of the anterior end of the calcaneum and midfoot dislocation

Figure 5: Twenty two-year-old farmer presenting with fracture of the anterior end of calcaneum with a followup of 14 months and an American Orthopedic Foot and Ankle Society score of 93. (a) Preoperative X-ray of foot lateral view and three dimensional computed tomography view showing fracture of the anterior end calcaneum (b and c) Postoperative X-ray showing adequate length restoration of lateral column (d and e) Followup X-rays foot anteroposterior and lateral views at 14 months showing fracture consolidation and no calcaneocuboid arthritis (f) Clinical photograph at 14 months followup showing good foot alignment

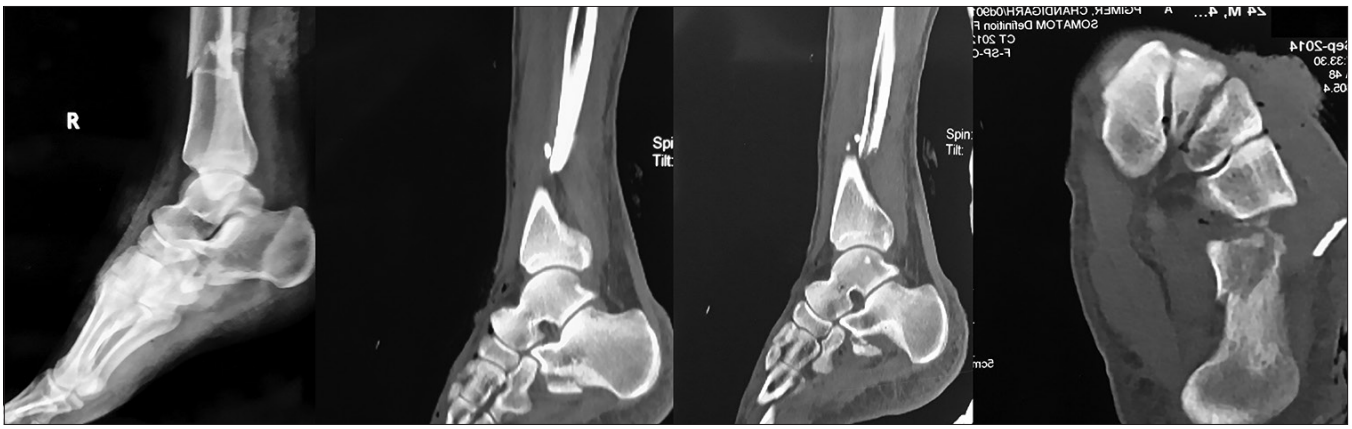

Figure 6: Preoperative X-ray and noncontrast computed tomography of the third case showing open fracture of the anterior end of the calcaneum with open Grade IIIb distal both bone leg fracture

referred to uniformly as the anterior process (*processus anterior)* of the calcaneum.[14] The anterior process calcaneum takes up the anterior third of the bone and is clearly distinguished by its lower height compared with the posterior portion.

The most frequent mechanism of fracture involving a part of the anterior end calcaneum is an inversion injury, with the foot in plantar flexion, leading to an avulsion of the bifurcate ligament.[3,4,8,10] This may occur when participants are wearing high heels, which may explain the higher incidence of this injury in females.[2,5] These patients may also have a calcaneonavicular coalition, long anterior calcaneal process, thickened anterior talofibular ligament, or thickened bifurcate ligament.[2,5] Commonly, with a sudden twist, there is an immediate pain on the outer aspect of the mid portion of the foot and discomfort on weight bearing

Figure 7: The third patient presenting with an open fracture of the anterior end of the calcaneum with a followup of 12 months and an American Orthopedic Foot and Ankle Society score of 82. (a) Preoperative Clinical photograph of foot showing open injury to the foot (b and c) Radiographs of the foot showing fracture anterior end of the calcaneum and distal leg (d) Postoperative clinical photograph showing good skin graft up take. (e) Postoperative X-ray showing adequate length restoration of lateral column (f) X-ray at 12 months followup showing good foot alignment

which is later often in retrospect diagnosed as an "*anterior end calcaneal fracture"*.

Another presentation of these injuries is as stress fractures; these are seen in sportsmen and are often associated with tarsal coalitions.[10,11] According to Pearce *et al*., the lack of normal motion resulting from a coalition leads to increased pressure on the anterior process of the calcaneus, which is impinged between the talus and the cuboid, resulting in a stress fracture.[10]

Other mechanisms described are forceful plantar flexion and a direct blow,[3,9] all of which are different from the current cases described [Table 1]. These fractures caused by noncompressive forces have been variously managed both operatively in the form of open reduction and fixation with screws[9,10] as well as by nonoperative management.[5] The outcomes and prognosis in that group are different, as column length alteration is never an issue. Nevertheless delayed detection of these fractures increases likelihood of painful nonunion and chronic pain, often with limitations of eversion of the foot.[8,13,15]

The cases described here had significant shortening of the lateral column which proves that excessive abduction of the foot was key mechanism of these injuries. A direct injury would on the other hand lead to mere crushing of the anterior process and would not lead to column shortening and thus abate the need for column length restoration. Fractures caused by compression of the cuboidal articular surface of calcaneum, commonly due to abduction forces on the forefoot have been reported previously in the literature.[6,7] As early as 1970, Hunt described a professional motorcycle racer whose foot was run over by a fellow biker; he sustained an abduction injury to the foot leading to fracture of the anterior end of the calcaneum. This patient was managed by open reduction and K-wire fixation, followup at 1 year revealed calcaneocuboid arthritis with mild pain.[7]

In another study, Dewar and Evans documented five cases of compression fractures of anterior end calcaneum; two were managed nonoperatively by plaster cast immobilization, while three cases underwent calcaneocuboid fusion. They concluded that treatment by plaster immobilization alone resulted in persistent disability; however, no objective criterion was used to assess outcome.[6]

Apart from these two studies,[6,7] there was no description of this mechanism of injury in the published literature. Over the last 20 years, the understanding of the foot columns, as well as the need to stabilize and regain column length, has significantly evolved.[16] The concepts are applicable to both columns of the foot and are now routinely used to understand displaced midfoot injuries. The crushing fracture of the anterior calcaneum, even if seen as an isolated midfoot injury, actually occurs after a significant laterally directed force disrupts and shortens the lateral column. It is important to note that some inherent ligamentous instability could be present on the medial side, which is often not obvious on routine radiographs. Dhillon and Nagi[16] previously published that an abduction force breaks the midfoot somewhere (maybe in the medial column), and this force causes crushing of either the anterior end of the calcaneum or the cuboid; so a crushing injury in the lateral column could actually be an undiagnosed or occult midtarsal dislocation. Some cases could have an obvious bicoulmnar fracture, where both columns are fixed and column lengths maintained. Unfortunately, due to limited understanding of this concept of multicolumnar injury for the foot, a limited crushing of the anterior calcaneum, with no obvious radiological injury elsewhere, is often treated nonoperatively by some surgeons with limited understanding of the foot injury biomechanics. This is also reflected in the two previous reports published,[6,7] and we thus were aggressive in the management of out cases, where lateral column length was regained and maintained with Kwires, with or without bone graft, and deforming forces were counteracted by the use of external fixators. Modern implants could allow the use of a spanning plate also, but limited availability and presence of wounds often makes us use minimal implants, often by external fixators which stabilize the column till healing.

The purpose of the current report is to highlight a few issues; anterior end of the calcaneum fractures can occur with varying deforming forces, and the inversion strain injuries are very different from eversion strain injuries. Method of managing these uncommon injuries also differ, as inversion strain injuries are avulsion fractures, and fixation of fragments or even nonoperative management in plaster of Paris casts could give good outcomes. On the other hand, abduction/eversion strain injuries, when they are significant enough to cause compression fractures, have very poor outcomes with nonoperative treatments. The emphasis should be on lateral column length restoration, which is done by any method, filling up voids with bone grafts, and keeping the length of the column intact using an external fixator in distraction mode. The application of a temporary plate spanning the anterior calcaneum, on to the cuboid, is also a good option, and employs the same principles.

The good to excellent functional outcome scores at >1-year followup in all three cases, using an objective functional outcome measure in the form of AOFAS midfoot score, revalidates our point.

Conclusion

It is important to understand the fractures of the anterior end of the calcaneum. The mechanism of trauma is very different from that of a conventional calcaneum fracture. Even the anterior end fractures are of 2 types; the less traumatic avulsion type injuries with smaller fractures, often missed, and the more traumatic crush injuries which shorten the lateral column and need good planning and understanding of mechanics to ensure good outcomes. Column length restoration and maintenance are key elements, and the calcaneocuboid joint can be salvaged in most cases. Some degree of distraction is needed for a sufficient period to allow bony and soft-tissue healing and long term walking support will ensure good to excellent outcomes.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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