

The Evolution of the Surgical Treatment of Displaced Intra-Articular Fractures of the Calcaneus

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Abstract

Over time the anatomy, clinical assessment, imaging, surgical techniques and implants, as well as the use of scoring systems has improved our ability to understand and treat complex injuries which result from intra-articular fractures of the calcaneus. The following article discusses the changing trends of management which ranged from non-operative management to open reduction and fixation to percutaneous fixation. The pros and cons of each option is discussed and why surgical management fell out and then in favour and is now considered standard of care for most cases.

Keywords: *Calcaneus; Intra-Articular; Displaced; Evolution; Displaced*

Abbreviations

CT: Computed Tomography; ORIF: Open Reduction and Internal Fixation; SF-36: Short Form-36; AOFAS: American Orthopaedic Foot and Ankle Society; MFS: Morse Fall Scale

Introduction

Calcaneal fractures represent 75% of all fractures affecting the foot and 1 - 2% of all fractures [1]. About 75% of them are intra-articular. These injuries may have long term consequences in terms of pain, disability, level of activity and recovery is often prolonged [1]. Due to potentially serious sequelae, controversy persisted with respect to the optimal treatment of calcaneal fractures, with some advocating for open reduction and internal fixation, and others recommending closed treatment [1,2].

Discussion

The calcaneus has a complex anatomy due to the undulating facets that articulate with the talus and cuboid [3]. The intricate relationships between the calcaneocuboid and talocalcaneal articulations are the basis for the complex kinematics of subtalar motion which allows for a normal gait [3,4]. While most authors have stressed the importance of the posterior facet [3,4], both the anterior and posterior subtalar articulations must be considered during the surgical management [3].

Displaced intra-articular calcaneal fractures are often associated with significant injury to cartilage, bone and surrounding soft tissues [5]. A high energy mechanism is often responsible for these fractures which require comprehensive evaluation of the patient to rule out associated injuries, for example, injuries to the spine, pelvis and tibial plateau [2,6-8]. The main aetiology includes falls from a height and motor vehicle accidents [6,7]. Calcaneal fractures may be considered to be a soft tissue injury with painful and rapid onset of swelling, ecchymosis and possibly fracture blisters [9]. Soft tissue management is therefore of paramount importance [9,10].

There is a relationship between abnormal anatomy of the heel post injury and poor clinical outcome [14] such as the moderate increase in the heel width and a decreased fibulocalcaneal distance caused by proximal and lateral displacement of the lateral wall or calca-

neal body or both [14]. When the heel remains shortened and widened, the talus remains dorsiflexed in the ankle mortise and the lateral wall causes impingement and binding of the peroneal tendons [6].

This injury most commonly occurs in patients in their productive years [7]. In managing these fractures, it is important to prevent sequelae and achieve work reintegration [7]. It thus ought to be treated by an experienced surgeon [11-14]. Inadequate or inappropriate treatment often results in loss of hind foot motion, persistent pain, angular motion and disability [5].

Improvements in imaging technology have allowed a three dimensional (3-D) analysis of the fracture's morphology and joint involvement which has provided the basis for newer classifications [15]. Several authors routinely use computed tomography (CT) when plain radiographs reveal an intra-articular fracture [2,6,7,10]. CT is helpful in planning surgery, including open or percutaneous procedures [16] and should only be done if surgery is going to be undertaken [8]. 3-D imaging has been introduced to more accurately detect intra-operative errors such as malreduction and misplacement of screws. The error may be corrected intraoperatively and is intended to reduce the need for reoperation [17,18]. CT has demonstrated that there is wide variability of pathology associated with calcaneal fractures [19-21].

Restoration of Bohler's angle is very important as it is associated with favourable results [19,22,23]. Decreased Bohler's angle suggests a lack of preservation of heel height [14]. In a randomized prospective cohort study, Loucks and Buckley [24] found that fractures with a markedly decreased Bohler's angle demonstrated a much poorer two year outcome regardless of treatment. Paul, *et al.* [22] found that no patient in their study with a restored Bohler's angle needed subtalar arthrodesis.

It is key to achieve anatomical reduction of the subtalar joint as well as restoration of the width, height, length and alignment of the calcaneus [6,14,16,25,26]. Although anatomical reduction is required to achieve a good result, it does not ensure this because of damaged cartilage from the traumatic insult. Poor results may also be related to significant comminution and/or poor surgical technique [16]. Buckley, *et al.* [13] suggested that a better reduction based on CT, had better clinical scores at an average of 6.3 years follow-up when matched with a conservatively treated group. Surgical patients with a small residual step-off had similar outcome as the conservative group.

Historically, displaced intra-articular calcaneal fractures were predominantly managed conservatively; however surgery has been more prevalent in the last 20 years [27]. In 1908 open reduction of calcaneal fractures were contraindicated by Cotton and Wilson. They recommended closed treatment using a medially placed sandbag and a laterally placed felt pad and a hammer to reduce the lateral wall [28]. They abandoned this by the 1920's in favour of treating malunions [29]. Bohler [30] advocated open reduction after waiting 6-10 days for the swelling to resolve. Under lumbar anaesthesia, he aimed to correct flattening and shortening with the correction being held by plaster dressing and two pins. Unfortunately there were technical problems with associated poor outcomes secondary to poor anaesthesia, limited radiography and a poor understanding of the principles of internal fixation [30]. Conn [31], who was dissatisfied with the state of treatment methods, reported on the use of delayed triple arthrodesis; however others were dissatisfied with triple arthrodesis [32]. Dick [33] in his small series concluded that patients undergoing primary arthrodesis were able to return to heavy work. He further argued that the initial damage of the joint surface may be such that traumatic arthritis of the subtalar joint develops even if subsequent reduction is achieved. Dick [33] thus advocated primary arthrodesis of the subtalar joint to avoid prolonged disability and unnecessary pain. Lindsay and Dewar [34] in his long term study found that primary subtalar arthrodesis was being performed unnecessarily and comparatively, a conservatively treated group did better. That article gained widespread acceptance thus causing surgical management to fall out of favour in the 1960's and 1970's [6].

Palmer [32] stated that although there was widespread recommendation and usage of Bohler's technique in Germany, America and Britain, that Bohler himself did not demonstrate much enthusiasm for his own technique in the 6th edition of his textbook because he felt that open reduction at the time, offered little advantage because of difficulty in maintaining a stable reduction. Palmer [32] utilised a standard lateral Kocker approach, traction via a calcaneal pin, elevation to achieve reduction of the depressed fragments, and iliac crest grafting to fill the defect to maintain the reduction which was unstable prior to grafting. Unlike conservative management which used

traction, the patient is out of bed a few days after surgery. He stated that his patients did well and many returned to work. Similar findings were reported by Essex-Lopresti [35] in which he described that when the articular surface was displaced, tongue or joint depression fragments occurred. He was able to percutaneously reduce the tongue type fractures, but had to perform open reduction for the joint depression fracture to achieve a reduction. Paley and Hall [14] noted that tongue type fractures have the best prognosis, whereas extensively comminuted fractures had a worse prognosis.

It appears contradictory that the subtalar joint would be managed differently from other weight bearing intra-articular fractures, but suboptimal results with surgery had prompted non-surgical management [36]. Proponents of open reduction and internal fixation noted that the main advantage was the avoidance of the sequelae of malunion [6]. Surgery when chosen must be done within three weeks post injury, because after this, early consolidation makes fragments difficult to separate and obtain adequate reduction. Also, it must be performed after soft tissue swelling subsides [6]. Currently there are numerous operative procedures [37], which may be divided by approach, implant type and whether treatment is one or two stages [37].

There have been few prospective, randomised trials performed to analyse the benefit of surgical and conservative treatments [11,22,38]. Lack of anatomical reduction in some comparative studies has potentially been the reason for an inability to demonstrate a difference in outcome between surgical and conservative groups [3].

Parmar, *et al.* [39] conducted the first randomised prospective study comparing surgical and conservative groups. Via a lateral approach, he performed open reduction of the posterior facet and K-wire fixation, but of note, tuberosity fragments were not fixed, and no scoring system was utilised. One therefore must question his results which demonstrated a statistically insignificant difference between the groups. Unlike Parmar, *et al.* [39] who used K-wires, Thordarson and Krieger [26] in their study used plate and screw fixation, post open reduction. Twenty five percent of the surgical group patients had pain on extremes of motion versus 100% in the conservative group. This was the first randomised prospective study to clearly show superior results in the surgical group. Despite this finding, Buckley, *et al.* [13] in critiquing this study stated that the numbers were small with likely patient selection bias, nonresponsive bias and a lack of stratification.

Randle, *et al.* [38] performed a Medline search from 1980 - 1996 and found only six articles comparing surgical and conservative management which met criteria for a meta-analysis. Randle, *et al.* [38] concluded that the strength of evidence to recommend surgery is weak and that a large prospective study was required. Despite improvements in modern operative intervention, there is still no consensus on classification, treatment, surgical technique, absence of a universal protocol of subjective, objective, and radiological evaluation of surgical results [2,6,14,40,41].

There has been a renewed interest in surgery since the 1980's [40]. Since then improvements in anaesthesia, introduction of antibiotics, preoperative CT scanning, intra-operative fluoroscopy and AO principle of internal fixation have allowed surgeons to achieve good results with surgical intervention for most fractures [42]. Goals of surgery include: 1) restoration of congruency of the posterior facet, 2) restoration of calcaneal height and width, 3) decompression of the subtalar space available for peroneal tendons, 4) realignment of the tuberosity in a valgus position and 5) reduction of the calcaneocuboid joint [2,11,17]. Other goals include unlimited pain free walking in ordinary shoes [22,37].

Operative fixation is technically challenging with significant learning curve [13,15,18]. Radnay, *et al.* [5] advocated ORIF for displaced intra-articular calcaneal fractures versus conservative treatment because ORIF allows for restoration of articular congruency, shape and alignment of the calcaneus. The reduction must be maintained until union. If post traumatic arthritis of the subtalar joint develops and a subtalar arthrodesis is required, its technique is technically easier, post ORIF than after conservative management. Calcaneal height is restored post ORIF, thus decreasing wound complications at the subtalar fusion [5].

Wound complications are the most frequently encountered in surgical treatment [10]. Appropriate timing of surgery and appropriate soft tissue handling reduces the risk [6,10]. The timing of surgery is such that there should be minimal swelling which will allow easy handling of soft tissue [9,10]. Wound complication rates from large series utilising the lateral approach and its modifications have varied [9]. High risk of infection has discouraged some authors from advocating ORIF [12,43]. The development of minor and major wound complications is a major concern due to the vulnerable, thin soft tissue envelope over the lateral calcaneal wall that is exposed intra-operatively [10,11]. Wound edge necrosis is seen in 2-10% of cases post standard osteosynthesis via an extensile lateral approach [21,25,37].

Infection rates have been said to be influenced by patient related risk factors e.g. diabetes and smoking [44], fracture related risk factors, e.g. highly comminuted fractures, open fractures [45], and the interval between the initial traumatic event and surgery [46]. Poeze, *et al.* [43] found that the rate of deep infections post ORIF was significantly related to the fracture load at an institution. He further stated that an institutional load of less than one fracture per month jeopardises the outcome of surgery of displaced intra-articular calcaneal fractures.

In an attempt to reduce wound complication rates an L-shaped, sharp angulated extensive lateral approach was introduced [25,42]. The incision utilises sharp dissection to raise full thickness flaps from skin to periosteum without separating the layers to preserve flap viability [10]. The extensile L-shaped is said to minimise the sequelae of peroneal tendonitis and devascularisation of the anterior skin flap and preserve the sural nerve [25].

Burdeaux [47] reported on his 21 years experience with the medial approach. Stated advantages included full weight bearing while wearing normal shoes by eight weeks as well as a reduced incidence of wound complications. The principal disadvantage is that 20% of patients required an additional lateral procedure due to fibulocalcaneal impingement, irritation of the peroneal tendon sheaths and consequently, difficulty wearing shoes. Mostafa, *et al.* [23] felt the medial approach is difficult with an increased risk of neurovascular injury and devascularisation of bone fragments.

Many authors have proposed closed reduction and minimal invasive osteosynthesis to minimise soft tissue complications [19,21,48]. In patients with severe neurovascular insufficiency, poorly controlled insulin dependent diabetes or critical soft tissue issues, closed reduction and minimally invasive osteosynthesis is an alternative to ORIF. Although reduction may be suboptimal in patients who have Saunders III and IV fractures, partial anatomical restoration potentially avoids the dreaded complications of open surgery [48]. Soft tissue complications such as wound edge necrosis or deep infections are rarely seen with percutaneous surgery [12,21]. Unfortunately, when there is inaccurate restoration of the posterior facet following closed reduction [19,37,48], even a 1 - 2 mm step-off may lead to a significant pressure redistribution throughout the posterior facet [49,50] and consequently inferior result [13].

Arthroscopically assisted percutaneous reduction and screw fixation has been developed to combine the advantages of minimally-invasive surgery with anatomic reduction of the posterior facet. Proper surgical timing and patient selection is important where the indication of percutaneous reduction include Sanders II and III fractures [12]. This should not be attempted after seven days [12]. Multiple reduction attempts are contra-indicated and ORIF may at this point be done via a small direct lateral approach by incorporating the stab incision [48]. Closed reduction is sometimes unsuccessful due to deep impaction of the posterior facet fragments or interposed soft tissue or smaller bony fragments which cannot be loosened [12].

The percutaneous approach minimises secondary trauma to the soft tissues which lead to decreased scar tissue formation around the ankle and subtalar joints and hence decreased stiffness to the respective joints [51]. With his percutaneous approach at a mean follow-up of 35 months, he achieved 70% subtalar and 90% ankle range of motion (compared to normal side).

Patient-oriented functional outcome scores e.g. SF-36 a standardised general health survey and the disease specific visual-analogue score provide both general and disease specific outcomes to lessen bias [13]. Westphal, *et al.* [40] analysed the outcome of the surgically treated patients by comparing AOFAS and MFS which is commonly used in the literature [5]. With the SF-36, painful and functional scores showed the highest difference in patients compared with normal people [40].

Age greater than 50 has been defended as a contraindication to surgery because of unfavourable outcomes [33]. Herscovici, *et al.* [41] achieved a 97% union rate, high patient satisfaction and an acceptable wound edge necrosis rate in this population is comparable to others.

In addition to the factors mentioned earlier, Buckley [13] in his randomised, controlled, multicentred statistical analysis showed that female patients not receiving worker compensation, younger males and patients with lighter workload all have a favourable profile with regards to good outcome following surgery.

Conclusion

Improved imaging technology, an increased understanding of the importance of anatomic restoration especially of the posterior facet, advances in surgical technique, in combination with proper patient selection have led to improved outcomes with surgical intervention.

Conflict of Interest

There are no financial conflicts of interest.

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