Minimally-invasive treatment of intra-articular fractures of the calcaneum

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doi:10.1302/0301-620X.88B12.17379 \$2.00

J Bone Joint Surg [Br]
2006;88-B:1634-41.
Received 2 November 2005;
Accepted after revision 25 July 2006

We describe the results of 287 intra-articular fractures of the calcaneum in 247 patients treated by minimally-invasive reduction and K-wire fixation between 1994 and 2003. There were 210 men (85%) and 37 women (15%). The most common cause of injury was a fall from a height in 237 patients (96%). Fracture classification was based on the method described by Sanders and Essex-Lopresti. All patients were operated on within 21 days of injury and 89% (220) within 48 hours. The reduction was graded as nearly anatomical (less than 2 mm residual articular displacement and satisfactory overall alignment) in 212 (73.9%) fractures.

There were 20 cases (7%) of superficial pin-track infection and five (1.7%) of deep infection. All healed at a mean of 6 weeks (3 to 19). Loss of reduction was observed in 13 fractures (4.5%) and a musculocutaneous flap was needed in three (1%).

The results were evaluated in 176 patients (205 fractures) with a mean age of 44.3 years (13 to 67), available for follow-up at a mean of 43.4 months (25 to 87) using the Creighton-Nebraska Health Foundation Assessment score. The mean score was 83.9 points (63 to 100). There were 29 (16.5%) excellent, 98 (55.7%) good, 26 (14.8%) fair and 23 (13%) poor results. A total of 130 patients (73.9%) were able to return to their original occupation at a mean of 5.6 months (3.2 to 12.5) after the injury.

Semi-open reduction and percutaneous fixation is an effective treatment for displaced intra-articular fractures of the calcaneum.

Fractures of the calcaneum constitute approximately 60% of all tarsal injuries, and are usually the result of a fall from a height.¹ The economic importance of the injury is considerable, as 80% to 90% occur in men in their prime working years.² As a result, they may be disabled for several years after the injury and many are unable to return to their original occupation.³ The treatment of these injuries remains controversial.² In the past, conservative treatment was preferred, generally with unsatisfactory results.

Although open reduction has been performed since the early 1930s,³ technical problems, infection and, on occasion, the need for amputation, prejudiced surgeons against operative treatment.

Over the last 20 years, however, developments in antibiotic prophylaxis, fracture fixation and imaging techniques have improved the results of operative treatment. It remains challenging with the possibility of serious complications, particularly in patients predisposed to infection because of systemic illness or local factors, such as blisters, swelling and open wounds.

Compared with open procedures, minimally-invasive techniques offer the prospect of a good reduction and fewer complications.⁴⁻⁶

The purpose of this study was to review our experience of minimally-invasive reduction and K-wire fixation in the treatment of intra-articular fractures of the calcaneum.

Patients and Methods

Between January 1994 and May 2003, 294 patients with 345 intra-articular fractures of the calcaneum were treated using a standard protocol of semi-open reduction and K-wire fixation. All patients with displaced intra-articular fractures were treated surgically. Only those with undisplaced fractures, extra-articular fractures, and fractures more than three weeks old were treated conservatively. All patients underwent clinical and radiological review at 6, 12 and 24 weeks, and at one year. After one year, 47 patients with 58 fractures could not be traced, leaving a total of 247 patients with 287 fractures.

The mean interval between injury and operation was 19 hours (6 hours to 21 days)

Fig. 1a

Fig. 1b

Diagram showing a) axial and b) lateral views of a calcaneal fracture. The depressed part of the posterior facet is elevated with a bone punch introduced through the primary fracture line while traction is applied.

and 89% (220) were treated within 48 hours of injury. There were 210 men (85%) and 37 women (15%). The most common cause of injury was a fall from a height in 237 patients (96%). The fractures were bilateral in 39 patients (15.7%) and compound in six (2.4%). A total of 24 (8.4%) were combined with a fracture of the thoracolumbar spine, and 12 (4.2%) were in patients with multiple injuries.

We studied the type of fracture, the degree of reduction (Gissane,^{2,3} Preiss^{7,8} and Bohler^{2,3} angles) and the height, length and width of the calcaneum, measured on initial, post-operative, and 12-week radiographs and one year after surgery.

Long-term results, at a mean 43.4 months (25 to 87) with a minimum follow-up period of two years were available for 205 fractures in 176 patients with a mean age of 44.3 years (13 to 67). These patients were evaluated using the Creighton-Nebraska Health Foundation score.^{9,10}

Each patient was initially evaluated with standard lateral and axial radiographs of the calcaneum. Computed tomography (CT; transverse and coronal views) was performed in those with displaced intra-articular fractures.¹¹ A lateral radiograph of the uninjured side was helpful in some cases.

The fractures were classified according to the Sanders et al¹² and Essex-Lopresti⁴ methods. Based on our review of the first 100 fractures, we modified the Essex-Lopresti system by adding a third type of fracture which was characterised by extensive comminution in the anterior part of the calcaneum, or in the region of the posterior articular facet. This type of fracture requires a different method of fixation.

There were 175 (61%) Sanders type II fractures,¹² 86 (30%) type-III and 26 (9%) type-IV. There were 183

(63.8%) joint-depression fractures, 72 (25.1%) tongue-type fractures and 32 (11.1%) comminuted fractures using the modified Essex-Lopresti classification.^{7,8}

Operative technique. This combines direct reduction of the displaced fragments of the articular surface under image-intensifier control with indirect reduction of the overall alignment and shape of the calcaneum.

The patient is placed in the lateral decubitus position on a radiotranslucent operating table with the injured limb uppermost. The image intensifier is introduced; good lateral, axial and Broden's views^{2,3} must be obtained before starting the procedure.

The operation is in four steps.

In the first, a 4.5 mm Steinmann pin is inserted from the medial side through a stab incision in the posteroinferior portion of the calcaneal tuberosity. Traction is applied manually through a traction bow in the long axis of the calcaneum, with alternating varus and valgus stress on the heel and the forefoot to disimpact the fracture and gain space for further reduction of the articular fragments. The varus position of the tuberosity fragment is corrected and reduced onto the sustentacular one.

The second step is reduction of the articular surface under image-intensifier control. In joint-depression fractures, a stab incision is made in the sole of the foot and the displaced posterior facet is elevated with a 3 mm to 4 mm bone punch advanced through the primary fracture line in the body of the calcaneum (Fig. 1). The entry point may be enlarged with a 3.5 mm to 4 mm drill. In tongue-type fractures, a 3 mm to 4 mm Steinmann pin is inserted lateral to the Achilles tendon into the superior portion of the calcaneal tuberosity. This is used to lever the rotated fragment of

Fig. 2a

Fig. 2b

Lateral view of a 'tongue-type' calcaneal fracture. a) The rotated fragment is elevated and (b) the reduced fragment is transfixated with Kirschner wire.

the posterior facet into place (Fig. 2). In complex fractures we have found it helpful to combine the two techniques (Fig. 3). Valgus stress is applied to the pin to reduce the posterior facet onto the intact medial portion of the posterior articular facet and the sustentacular fragment. Once reduction is confirmed with the image intensifier, the fracture is held with a 2 mm K-wire. An additional 2 mm K-wire is usually placed parallel to the pin, medial to the tendo Achillis.

The third step is to compress the heel in order to impact the lateral wall. This reduces the calcaneal width and prevents lateral impingement. Lateral compression of the heel should not be performed unless the articular fragments are fully reduced, as this would make further reduction of the articular fragments very difficult. Once a good reduction has been achieved, K-wires are passed transversely from the tuberosity into the sustentacular fragment (Fig. 4).

In the last step, the reduction is secured by six to eight 2 mm K-wires, the number of which will vary according to the type of fracture and the degree of comminution (Fig. 5). K-wires should secure both the reduced articular surface and the overall alignment (Fig. 6).

In highly comminuted fractures involving the calcaneocuboid joint (type III^{7,8}) it is useful to advance the K-wires into the cuboid, and occasionally the talus, as recommended by Levine and Helfet,⁶ as the purchase of K-wires in the calcaneum alone may not be sufficient.

Finally, the wires are cut flush with the skin and a soft, bulky dressing is applied. The patient can start range of movement exercises of the ankle and subtalar joint on the second post-operative day, and may walk without bearing weight on the affected limb. Most patients with unilateral fractures can be discharged after three to four days.

The use of supplementary bone graft is controversial. We introduced it percutaneously through the primary fracture gap in five patients at the beginning of the study, but have not seen secondary collapse in any subsequent patient with

a comminuted fracture treated without bone grafting. There is no evidence to support the use of bone graft,² and no apparent radiological or functional advantage.^{13,14} We do not consider that its routine use is indicated.

The K-wires were removed after a mean of 8.4 weeks (8 to 10), depending on the type of fracture and the degree of union, and partial weight-bearing was allowed with full weight-bearing at a mean of 11.8 weeks (11 to 13.6).

Results

The reduction, as measured radiologically by the change in Böhler^{2,3} and Gissane^{2,3} angles and the height and width of the calcaneum, is shown in Table I. The reduction was graded as nearly anatomical (less than 2 mm residual articular displacement and satisfactory overall alignment) in 212 fractures (73.9%). In the early post-operative period there were 13 cases (4.5%) of loss of reduction resulting from inadequate primary fixation with K-wires. Six were successfully revised. There were 20 cases (7%) of superficial pin-track infection, all of which resolved with a short course of antibiotics and regular dressing with antiseptic solution.

Deep infection with osteomyelitis developed in five patients (1.7%), two after a compound fracture and three in a closed injury. In each case the K-wires were removed and the wound debrided. This required a partial resection of the extra-articular portion of the calcaneum in two cases. In three cases a soft-tissue defect was treated with the use of a musculocutaneous flap; two of these had been treated for a compound fracture, with severe soft-tissue injury. The third case was a diabetic patient treated for a closed fracture. He developed a pin-track infection, which, owing to insufficient local care and delayed debridement, progressed to osteomyelitis with a soft-tissue defect. All these cases eventually healed and none required amputation.

Spontaneous fusion of the subtalar joint occurred in eight patients (3.2%) with highly comminuted fractures.

Fig. 3a

Fig. 3b

Fig. 3c

Fig. 3d

Radiograph of a complex calcaneal fracture. A Steinmann pin is used for the initial leverage of the articular fragment. a) Pin is inserted below the displaced articular fragment, b) the fragment is levered up and c) anterior bone impactor is used for additional elevation of the articular fragment. d) The final elevation of the fragment by the impactor to the level of the undisplaced part of the articular surface.

Mild to moderate signs of post-traumatic subtalar osteoarthritis, evaluated radiologically as narrowing of the joint space and subchondral sclerosis were present in 246 fractures (85.7%) but pain in the subtalar joint was present in only 37 (12.9%).

The long-term results were evaluated in 176 patients with 205 fractures. The mean Creighton-Nebraska Foundation score⁹ was 83.9 points (63 to 100). In 29 patients (16.5%) the results were excellent, in 98 (55.7%) good, in 26 (14.8%) fair, and in 23 (13%) poor. The results of the patients with tongue-type fractures were slightly better, with a mean score of 86.5 (71 to 100) than those with joint depression-type fractures, who had a mean score of 81.2 (63 to 92). This may be because of the relative ease of

reduction of the joint surface in Sanders type IIB and IIC tongue-type fractures. The results of patients with a Sanders type-II fracture (mean score 87.6 (70 to 98)) were better than those patients with a Sanders type-IV fracture (mean score 69.4 (63 to 95)). This is comparable with the results of other series with similar patient populations,^{12,13} in which poor results with Sanders type-IV fractures were reported even after open reduction and internal fixation. Unfavourable results in such patients are usually attributed to extensive trauma to the articular cartilage. The more severe soft-tissue trauma seen in some of these patients may, however, also be a contributory cause. The mean score of patients with bilateral calcaneal fractures in our series was 72.6 (63 to 81). The

Fig. 4

Diagram showing the axial view of the calcaneal fractures after reduction and insertion of transverse Kirschner wires.

majority of these patients (30 of 39) sustained their injury in a fall from a substantial height, with this group containing a greater proportion of more severe fracture types (Sanders type III or IV in 72% (28 of 39)) as well as a greater proportion of accompanying injuries. For example, 16 of the 24 spinal fractures in our series occurred in patients with bilateral calcaneal fractures.

After a mean of 5.6 months (3.2 to 12.5), 130 patients (73.9%) were able to return to their original work.

Discussion

Conservative treatment of the displaced intra-articular fracture is unlikely to result in normal function because of secondary arthritis and malunion of the calcaneum.^{3,15-19} Thordarson and Krieger²⁰ using the American Orthopaedic Foot and Ankle Society Score (AOFAS) scoring system showed surgically-treated patients scoring 86.7%, whereas patients treated non-operatively only managed 55%. Crosby and Fitzgibbon¹⁰ originally treated all fractures of the calcaneum non-operatively. Because the results were poor, they began to treat patients with displaced fractures surgically and found that the results improved significantly. In a recent meta-analysis by Randle et al,¹⁵ comparing operative and non-operative treatment of intra-articular fractures of the calcaneum, patients treated operatively fared better in terms of reduced pain, earlier return to work, reduced heel width, improved gait and better radiological outcomes. Buckley et al²¹ also found significantly better results in patients treated surgically, but there is still no consensus on surgical approach and technique.

Fig. 5a

Fig. 5b

a) Radiograph showing overall reduction of the calcaneal fracture and fixation with multiple Kirschner wires. b) Two-dimensional CT scan showing reduced articular facet held by Kirschner wires, with restoration of both Böhler and Gissane angles.

The medial approach described by McReynolds²² and used in a large series by Burdeaux²³ allows for direct reduction and fixation of the medial wall and the sustentacular fragment. The articular surface is reduced indirectly, as this is safer and has fewer and less serious soft-tissue complications than surgery through an extensile lateral approach. Burdeaux²⁴ and Parmar, Triffit and Gregg²⁵ believe that anatomical reduction of the posterior facet is not critical for good clinical results, and that it is not as important as was previously assumed since the disabling pain after the fracture does not arise from secondary subtalar arthritis. Lindsay and Dewar²⁶ agree that few symptoms arise from the subtalar joint alone. Paley and Hall²⁷ believe that there is a relationship between gross anatomical abnormality of the

Fig. 6a

Fig. 6b

Fig. 6c

Fig. 6d

Coronal and transverse CT scans (a and b) before and (c and d) after reduction. There is congruent articulation of the posterior facet with only a minimal gap in the articular surface. The length of the body of the calcaneum has been restored and the post-traumatic varus deformity corrected.

Table I. Mean values (ranges) of Bohler and Gissane angles and the calcaneal height and width

	Böhler angle (°)	Gissane angle (°)	Calcaneal height (mm)	Width of the calcaneum (mm)
After injury	4.5 (-27 to 36)	140 (67 to 181)	34 (28 to 57)	59 (31 to 78)
After surgery (immediately)	27.5 (-12 to 44)	125 (102 to 135)	51 (42 to 63)	48 (31 to 62)
One year after surgery	23.0 (6 to 40)	132 (102 to 148)	48 (36 to 62)	48 (32 to 59)
Uninjured calcaneum	34.2 (26 to 44)	124.5 (118 to 132)	52 (44 to 64)	45 (32 to 58)

heel and a poor clinical outcome, and stresses the importance of restoring the overall anatomy of the calcaneum.

The lateral extensile approach is the most widely used.^{3,28} Surgeons employing this approach including Sanders,^{3,12,13} Benirschke and Sangeorzan,¹⁷ Zwipp et al²⁹ and Eastwood et al¹ stress the importance of anatomical reduction of the posterior and middle facets. The lateral surface of the calcaneum is better suited to the application of plates and rigid fixation.

Serious complications are associated with this approach, the most common being wound dehiscence, which may occur as much as four weeks after surgery. Folk, Starr and Early³⁰ reported that in 190 fractures, four patients required amputation, there was a 25% wound complication rate, 22 patients required early removal of their implants and 11 needed flap cover. Abidi and Gruen²⁸ reported problems with wound healing in 32% of their

Fig. 7

Radiograph showing the final result six months after the injury.

cases. Sanders¹² noted three amputations and five free flaps in 120 patients. Schuler et al³¹ found that their patients took a mean of 47 days to heal. Schuler et al³¹ observed that the better the correction of Böhler's angle and the restoration of calcaneal height and length, the greater the soft-tissue tension, resulting in wound dehiscence. However, Benirschke and Sangeorzan,¹⁷ did not encounter any serious complications.

To prevent these potentially disastrous complications, careful patient selection is necessary. Diabetics, smokers, patients with vascular impairment, compound fractures or fractures with blisters and persistent swelling should be excluded. Surgery should be undertaken only when the swelling subsides, usually seven to ten days after the initial injury.

By contrast, our minimally-invasive technique has very few contraindications and excludes only patients with infected blisters and those who are too unwell for surgery.^{7,8} The overall reduction of the calcaneum, as judged by restoration of length, height, width and correction of varus deformity, is very good (Fig. 7). Reduction of the articular surface was good on image intensification and on the CT scans.

The clinical results of this technique compare favourably with those of patients treated by open reduction, particularly because patients with highly comminuted fractures were included in our study.

Our figures of 7% superficial and 1.7% deep infection are significantly lower than those in most series of formal open reduction. No patient required amputation.

Patients treated using our percutaneous technique should be operated on as soon as possible after injury, while for open reduction, using the extensile lateral approach an

interval of five to nine days between the trauma and surgery has been advised to prevent complications with wound healing.^{3,28,31} Attempts to reduce hospital stay by pre-operative out-patient management of patients to be treated by open reduction has proved unsuccessful. Schuler et al³¹ had problems in wound healing in 42.5% of patients operated on through a lateral extensile approach after a mean of ten days as out-patients, compared with only 16.6% when treated as in-patients.

Our technique requires manipulation of the posterior facet without full exposure. Other authors advocate a similar method only for fractures in which the posterior facet remains attached to the tuberosity fragment. This permits the Essex-Lopresti manoeuvre and relatively easy manipulation. Tornetta^{32,33} reported 46 patients treated with percutaneous fixation, of whom 39 had a Sanders type-IIC fracture and seven a type-IIB. He believes that Sanders type-IIC fractures, where the entire posterior facet is in continuity with the tuberosity fragment and the facet itself is intact, are best suited for percutaneous fixation. He reported 85% excellent or good results, and concluded that for selected fracture types the method gives comparable or possibly better results than open fixation.

Levine and Helfet,⁶ in their series of intra-articular fractures of the calcaneum treated with a minimally-invasive technique, were surprised that subtalar movement was almost completely preserved despite an articular surface reconstruction described as 'nearly anatomical'. They believe that minimal dissection results in less post-operative swelling, less peri-articular scarring and an improved range of movement than formal open reduction, despite imperfect restoration of the joint surface.

Thermann et al¹⁹ advised minimally-invasive fixation for cases with severe soft-tissue contusion, compound and Sanders type-IV fractures, and in multiply-injured patients. Rammelt et al³⁴ advocated percutaneous reduction of fractures of the calcaneum with severe soft-tissue compromise, and in patients in whom there are systemic contraindications to open surgery. He believes that it is suitable for Sanders type-IIC fractures and that, if used for Sanders type-IIA or IIB fractures, should be performed under arthroscopic control of reduction of the articular fragment.

In our series, both joint-depression and tongue-type fractures of all grades of severity (Sanders type II, III, IV) were treated using the same protocol. Both the extra-articular anatomy and joint congruity were restored in most of our patients, resulting in 72% good to excellent long-term results. Carefully performed semi-open reduction and percutaneous fixation is an effective treatment for displaced intra-articular fractures of the calcaneum, especially in patients where formal open reduction is considered to constitute a significant risk.³⁴⁻³⁶

On evaluating our data, as well as reviewing the literature, we conclude that:

1) joint depression fractures (Sanders type II, III) are generally difficult to reduce. The results were slightly inferior

to those of tongue-type fractures of comparable severity but the anatomy of the calcaneum was well restored.

2) Tongue-type fractures (Sanders IIB, IIC), can be successfully treated using a minimally-invasive technique. Patients with tongue-type Sanders type-III fractures do not do as well but gain good overall alignment.

3) All Sanders type-IV fractures should be treated with a minimally-invasive technique, as many are accompanied by severe soft-tissue trauma. Formal open reduction does not give a good functional result, even in the most experienced hands,^{9,11} and the percutaneous technique will safely restore overall calcaneal anatomy.

4) All displaced intra-articular fractures in patients at increased risk from a formal open reduction can be treated safely with a minimally-invasive technique.

Because this study was performed over a number of years, some of the clinical data was collected at the authors' (J. Stulik, J. Stehlik, M. Rysavy) previous institutions. We would particularly like to acknowledge the Department of Orthopaedics and Trauma, 3rd Faculty of Medicine, Prague, Srobarova 50, and the Department of Orthopaedics and Trauma, Klaudianova Neocnice, Mlada Boleslav, Czech Republic. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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