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Minimally invasive treatment of calcaneal fracture

Guangming Zhang, Shenglong Ding and Zhiyong Ruan

Abstract

Objective: This study was performed to analyze the outcomes of calcaneal fractures using a minimally invasive internal fixation method with a thin plate and bone grafting.

Methods: This retrospective analysis included 21 patients treated using our minimally invasive approach. The outcome measures were the change in the Bohler and Gissane angles and the calcaneus width after fixation. The clinical outcomes were evaluated by the Maryland foot scoring system and assessment of soft tissue complications.

Results: The follow-up time was 12 to 18 months. The Bohler angle, Gissane angle, and width of the calcaneus were significantly different between the preoperative and postoperative periods. The rate of excellent and good outcomes was 85.7% according to the Maryland foot scoring system. The incidence of soft tissue complications was 14.3%.

Conclusion: Treatment of calcaneal fractures using a minimally invasive internal fixation method with a plate and bone grafting provides good to excellent clinical outcomes with few soft tissue complications.

Keywords

Minor incision, anatomical plate, complication, intra-articular fracture, subtalar joint, bone grafting

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Introduction

Calcaneal fractures remain one of the most challenging problems for orthopedic surgeons. Calcaneal fractures account for about 2% of all fractures, and 60% to 75% are displaced intra-articular fractures.[1,2] Reliable reduction is difficult to

Orthopedics Department, Qingpu Branch of Zhongshan Hospital, Fudan University, Shanghai, China

Corresponding author:
Zhiyong Ruan, Orthopedics Department, Qingpu Branch of Zhongshan Hospital, Fudan University, Gongyuan Dong Road No. 1158, Shanghai 201700, China.
Email: xyrzy@hotmail.com

achieve with nonoperative treatment of a displaced intra-articular calcaneal fracture, and malunion of the fracture and subtalar arthritis readily occur.[3] In contrast, open reduction and internal fixation of displaced intra-articular calcaneal fractures can effectively restore the anatomical morphology of the subtalar articular surface and calcaneus.[4,5] Kirschner wires (K-wires), lag screws, and steel plates can be selected as internal fixation materials based on the characteristics of the fracture. A plate can support a comminuted fracture and bone defect. Moreover, the use of a thin locking plate not only ensures the strength of fixation but also reduces the extent of soft tissue interference. Therefore, open reduction and internal fixation with a plate is widely used for treatment of intra-articular calcaneal fractures in clinical practice. However, plate fixation requires a relatively large incision and extensive soft tissue dissection, which increase the risk of postoperative complications such as wound edge necrosis and infection.[6–8]

We were interested in determining whether reduction, bone grafting, and plate fixation by a small incision can reduce soft tissue complications. We hypothesized that minimally invasive treatment of calcaneal fractures would increase patient satisfaction and lower the incidence of complications. Therefore, we performed a retrospective cohort study to measure the outcomes of reduction, bone grafting, and plate fixation by a small incision.

Patients and methods

Patients who were treated for calcaneal fractures in our department from December 2014 to December 2016 were retrospectively analyzed. The inclusion criteria were a unilateral closed calcaneal fracture, available preoperative and postoperative imaging data, and complete follow-up data. The exclusion criteria were old fractures, a history of surgery, calcaneal tumors, and concomitant serious complications. Prior to surgery, lateral and axial radiographs and computed tomography scans of the affected calcaneus were obtained (Figure 1). Our study methods were approved by our institutional review board, and all patients provided written informed consent.

Surgical technique

The patients were placed in the lateral decubitus position, and the procedure was performed under general anesthesia. A tourniquet was applied to the upper thigh. Percutaneous reduction was achieved using K-wires to correct the subtalar surface. At the same time, varus or valgus deformity of the calcaneal tuberosity was corrected using a bone hook. After the reduction was deemed satisfactory under fluoroscopy, the fracture was fixed using K-wires. A small 3- to 4-cm longitudinal incision was subsequently made anterior to the Achilles tendon, and a second 1-cm incision was made at the calcaneocuboid joint for assistance. The flap beneath the deep fascia was opened while taking care to protect the surrounding soft tissue and peroneus tendon. Allograft bone was used to fill the large defect. Under fluoroscopy, an appropriately sized anatomical plate was selected for placement outside the flap. Three K-wires were used to fix the position of the steel plate and facilitate fluoroscopy. The plate was then inserted into the interval between the peroneus tendon and the lateral wall of the calcaneus. After the plate was fully inserted, the K-wires were inserted into the original holes. The screws were twisted in after percutaneous drilling (Figure 2). After the position of the plate and screws was deemed satisfactory, the wound was flushed and a drainage tube placed *in situ*. Intermittent suturing was

Figure 1. Preoperative lateral X-ray image shows a reduced Bohler angle (a) and Gissane angle (b). Preoperative computed tomography scans show the displaced and compressed articular surface of the calcaneus.

used to close the incision, and an elastic bandage was applied.

Postoperative management

The leg was maintained in an elevated position to prevent swelling, and the drainage tube was pulled out when the drainage volume was <50 ml. A postoperative radiograph was repeated for all patients (Figure 3). The patients were encouraged to exercise their toes and ankle joints on the first postoperative day. The wound was cleaned every 2 days until the sutures were removed, approximately 2 weeks after surgery. Full weight bearing was initiated 3 months after surgery.

Measured outcomes

The calcaneal width and the Bohler and Gissane angles were measured as anatomical parameters before surgery and on postoperative day 3. Soft tissue and

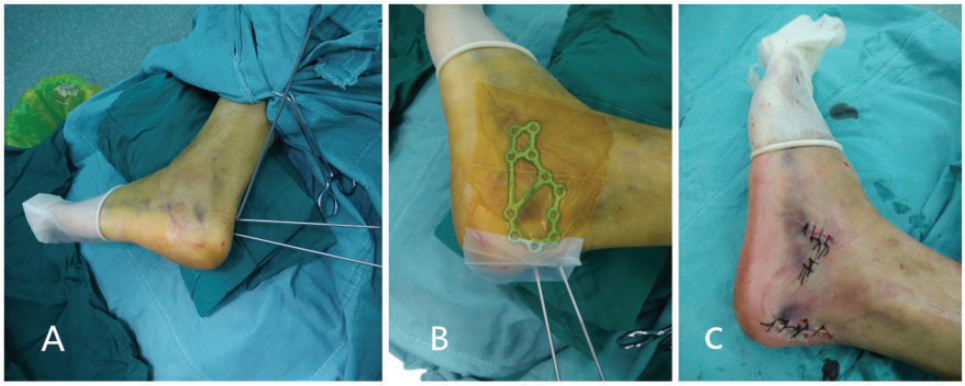

Figure 2. Operative procedure. (a) K-wires are used for fracture reduction and correction of varus or valgus deformity. (b) An appropriately sized plate is placed outside the flap, and three K-wires are used to drill holes from the steel plate holes for fixing position. (c) Minimally invasive incision.

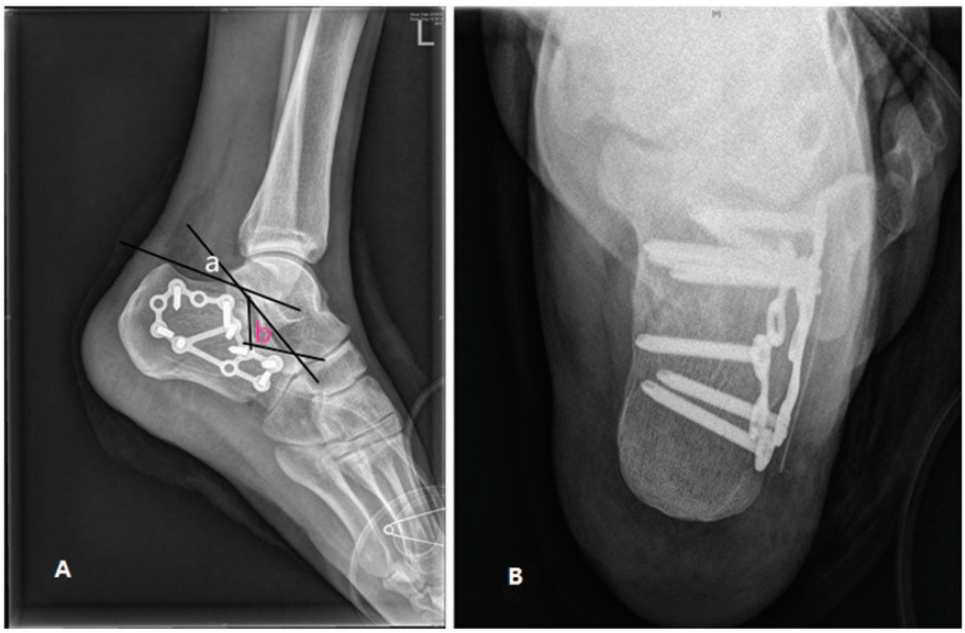

Figure 3. Postoperative lateral radiograph of the calcaneus shows anatomical reduction of the articular surface and correction of the Bohler angle and Gissane angle. Postoperative axial radiograph of the calcaneus shows satisfactory recovery of the calcaneus width.

incision-related complications were also recorded. Clinical functional outcomes were evaluated using the Maryland foot scoring system when the patients underwent a postoperative examination at $\geq$1 year postoperatively. Long-term postoperative radiographs are shown in Figure 4. The Maryland foot scoring system includes patient-reported pain, function (gait and functional activities), and cosmesis.

Figure 4. Postoperative long-term radiograph shows that the calcaneus has no loss of calcaneal height or varus deformity. The subtalar joint has mild arthritis.

Statistical methods

All data were analyzed by StataMP 13.1 statistical software (StataCorp, College Station, TX, USA) and are expressed as mean ± standard deviation. The preoperative and postoperative calcaneal anatomical parameters were compared by the t-test. Statistical significance was defined at the 5% ($p \leq 0.05$) level.

Results

In total, 53 patients were included in the present study. Twenty-one patients underwent minimally invasive treatment, the remaining patients underwent traditional open reduction and internal fixation because the articular surface was badly broken or the surgeon preferred this approach. The minimally invasive treatment group comprised 20 (95.24%) men and 1 (4.76%) woman. Their mean age was 46 years (range, 28–66 years). Five patients had Sanders type 2 fractures, 12 patients had Sanders type 3 fractures, and 4 patients had Sanders type 4 fractures (Table 1). Treatment was provided within 2 weeks of the injury. The Bohler angle improved from a preoperative mean of 17.25° (range, 13.1°–21.4°) to a postoperative mean of 33.18° (range, 27.91°–38.45°). The Gissane angle improved from a preoperative mean of 93.58° (range, 88.19°–100.57°) to a postoperative mean of 125.23° (range, 120.00°–130.46°). The postoperative improvement in the Bohler and

Table 1. General information and clinic outcomes of patients.

Case	Sex	Age (years)	Sanders classification	Wound complications	Follow-up time (months)	Maryland score
1	Male	45	2	None	13	90.5
2	Male	55	2	None	15	85.7
3	Male	43	2	None	16	83.4
4	Male	47	2	None	17	85.6
5	Male	39	3	None	18	93.4
6	Male	59	3	None	12	75.8
7	Male	30	3	None	12	92.3
8	Male	65	3	None	13	76.8
9	Male	55	3	None	14	85.4
10	Male	36	3	Inflammation	16	89.4
11	Male	39	3	None	17	93.3
12	Male	46	3	None	15	83.5
13	Male	47	4	None	13	70.5
14	Male	33	4	None	12	90.2
15	Male	39	4	None	13	82.3
16	Male	54	4	None	14	74.3
17	Male	29	3	None	15	72.4
18	Male	66	3	Superficial infection	13	89.0
19	Male	28	3	None	12	90.5
20	Male	60	3	Inflammation	13	83.4
21	Female	53	2	None	15	87.8

Gissane angles was highly significant ($p < 0.01$) (Table 2). The mean follow-up time was 14.2 months (range, 12–18 months). According to the Maryland foot score, the outcomes of 6 patients were excellent (90–100 points), those of 12 patients were good (75–89 points), and those of 3 patients were fair (50–74 points). The rate of excellent and good outcomes was 85.7% (18/21). The rate of soft tissue complications was 14.3% (3/21) (Table 1) and included wound inflammation in two patients and superficial wound infection without deep infection after using antibiotics and application of alcohol compresses in one patient.

Discussion

The calcaneus is the most considerable weight-bearing tarsal bone, which makes it vulnerable to injury. The purposes of calcaneal fracture treatment are to restore the normal anatomical relationship of the calcaneus, maintain the stability after reduction, and restore the function of the affected foot to the maximum extent possible. The traditional approach to open reduction and internal fixation provides sufficient exposure and firm fixation but is associated with a high rate of soft tissue complications; the incidence rate of incision-related complications is as high as 30%.[8] In clinical practice, patients with a poor soft tissue condition, contraindications for open surgery, and a simple type of calcaneal fracture are treated by minimally invasive operations involving a new concept around fracture treatment. The principle minimally invasive techniques include percutaneous reduction and internal fixation, external fixation, internal

Table 2. Radiological outcomes before and after the operation.

	Bohler angle	Gissane angle	Calcaneal width, mm
Preoperative	$17.25^\circ \pm 4.15^\circ$	$93.58^\circ \pm 5.19^\circ$	65.35 ± 3.56
Postoperative	$33.18^\circ \pm 5.27^\circ$	$125.23^\circ \pm 5.23^\circ$	60.10 ± 2.37
p	<0.001	<0.001	0.043

reduction and fixation via the sinus tarsi, percutaneous balloon dilatation, and arthroscopic-assisted reduction.[9–14] These minimally invasive surgical procedures have the advantages of lowering the incidence of soft tissue complications, thus providing a better treatment effect than extensive open reduction and internal fixation for some types of calcaneal fractures.

Plates can effectively resist rotation and axial stress to achieve stable fixation and are associated with low rates of loosening and fixation failure.[15] As expected, in our case series, no screw loosening or plate breakage occurred during follow-up. The main reason is that plate fixation can adapt well to the anatomical and biomechanical characteristics of the subtalar and calcaneocuboid joint.[16] Plate fixation using a sinus tarsi approach, which is currently popular, provides direct reduction of the articular surface through the incision, and the plate is designed to support the articular surface but without fixation of the calcaneal fracture below.[17] For this reason, we selected an anatomical plate for internal fixation because it can both restore the articular surface and support the calcaneus below.

In our series of 21 cases, the Bohler angle, Gissane angle, calcaneal width, and calcaneal function recovered to clinically acceptable levels in all patients. Our approach to open reduction and internal fixation is suitable for patients with a poor soft tissue condition and fresh closed Sanders type 2 and 3 fractures. It has the advantages of minimal trauma, reliable fixation, and minimal soft tissue complications. Our method is be suitable for selected Sanders type 4 fractures that have a low degree of compression of the articular surface. Our technique is not suitable for reduction of extensive articular fractures, which are technically difficult and prolong the operative time.

Compared with the traditional extensive lateral L-shaped incision, we used two small incisions; this simplifies the surgical approach, produces less trauma, reduces blood loss, avoids the risk of skin necrosis caused by destruction of the local blood supply, lowers the risk of wound infection, shortens the hospital stay, and lowers the overall costs of the treatment. However, several limitations of our study should be noted before interpreting our findings for clinical practice. The foremost limitation is the low number of cases ($n = 21$), the relatively short follow-up period (12–18 months), and the retrospective and single-center design, such that the effect of selection bias cannot be denied. The front end of the plate can easily impinge the peroneal tendon; thus, care is required during surgery. Previous studies have reported on the outcomes of the traditional surgical method for open reduction and internal fixation of intra-articular calcaneal fractures; we did not include this comparison in our study. Despite these limitations, we believe that the results of this study can be useful in the future development of prospective cohort studies and randomized controlled trials regarding the effectiveness of treatment for calcaneal fractures.

Conclusion

Treatment of calcaneal fractures using a minimally invasive internal fixation method with a thin plate and bone grafting can provide excellent or good clinical outcomes with few soft tissue complications.

Author contributions

GZ and ZY planned the study and performed the operations. GZ and SD measured the anatomical parameters of the calcaneus. SD collected and analyzed the data.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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ORCID iD

Guangming Zhang https://orcid.org/0000-0003-0449-6536

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