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Treatment of calcaneal fracture with calcaneal reduction forceps and external fixation

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Research article

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Abstract

Background:The optimal treatment of displaced intra-articular calcaneal fractures remains controversial.Conservative treatment has been proven to be ineffective for these fractures. Usually,surgical treatment methods include open reduction and internal fixation, arthroscopic-assisted reduction,balloon dilatation and plasty.However,there is no consensus on which methods are more effective.This paper reports the clinical effect of the minimally invasive treatment of calcaneal fractures by closed reduction using calcaneal plastic reduction forceps combined with threaded-pin external fixation.

Method:The clinical data of 16 patients,including 14 males and 2 females,with a unilateral calcaneal fracture were analysed retrospectively.The Bohler angle,Gissane angle,and calcaneal width, height and length were measured before and after the operation.The ankle function was evaluated according to the AOFAS score at 6 and 12 months after the operation.

Result:The average Bohler angle was 16.7 before the operation and 25.8 after correction; the average angle at the final follow-up was 25.2. The average Gissane angle before and after the operation was 103.6 and 120.9, respectively; the average angle measured at the final follow-up was 119.6. The average calcaneal width before and after the operation was 39.5 mm and 35.2 mm, respectively; the average width measured at the final follow-up was 36.5 mm. The average height before and after the operation was 46.9 mm and 48.5 mm; the average height measured at the final follow-up was 48.9 mm.The average length before and after the operation was 67.5 mm and 71.2 mm, respectively; the average length measured at the final follow-up was 70.9 mm. The average AOFAS score was 60.1 at 6 months after the operation and 80.6 at 12 months after the operation, which was significantly higher than the average AOFAS score at 6 months after the operation ($P < 0.001$).At the final follow-up, the AOFAS score was excellent, good, moderate,and poor in 11 cases, 3 cases,1 case and 1 case,respectively,with a rate of excellent and good scores of 87.5%.

Conclusion:The application of closed reduction using calcaneal plastic reduction forceps combined with threaded-pin external fixation is effective for the treatment of displaced calcaneal fractures, with a simple procedure, minimal trauma, fewer skin and soft tissue complications, and satisfactory clinical results.

Background

Calcaneal fractures are a common lower limb injury, accounting for 2% of all fractures and 60% of tarsal fractures[1]. High-energy injury is one of the main causes of calcaneal fractures, such as injuries sustained by falling from a height or in traffic accidents; while calcaneal fractures can be intra- or extra-articular, 75% of these fractures are intra-articular[2]. The treatment of intra-articular calcaneal fractures is a serious challenge for every trauma surgeon.

Because of the unique structure of the calcaneus and the amount of force it bears due to the weight of the human body, the anatomical structure of the calcaneus should be restored as much as possible after fracture to reduce the occurrence of traumatic subtalar arthritis[3,4]. Calcaneal fractures are usually treated conservatively or surgically. However, there is no consensus on the best treatment. Studies have shown that the prognosis after non-surgical treatment is generally poor. The main reasons for these poor results are difficulty in maintaining reduction and a loss of shape, which lead to widening of the calcaneus, reduced subtalar joint activity, muscle imbalance, and peroneal tendon injury or secondary osteoarthritis[5,6]. Percutaneous balloon angioplasty, percutaneous arthroscopic-assisted reduction and internal fixation, open reduction and internal fixation, and primary arthrodesis are the main surgical treatment methods[7–10]. Regardless of the method, surgery carries the risk of complications; traditional open reduction and internal fixation can easily lead to skin necrosis and deep infection. Once bone cement leaks into the subtalar joint space, percutaneous balloon dilatation will cause joint surface wear and joint movement limitation. Arthroscopic-assisted technology can be used for manipulations in the small subtalar joint space; however, articular cartilage can easily be damaged with such methods, which also have high requirements for the fine manipulations. Therefore, the range of indications for such methods is narrow. Percutaneous reduction or external fixation is a minimally invasive technique. A preoperative CT scan can reduce the risk of open surgery by facilitating the reduction and stabilization of most displaced fractures. Magnan et al.[11] reported the treatment of 54 consecutive closed and displaced intra-articular calcaneal fractures with miniature external fixators; an excellent or good clinical outcome was achieved in over 90% of patients.

The purpose of this study was to demonstrate the minimally invasive treatment of 16 calcaneal fractures by closed reduction using calcaneal plastic reduction forceps and threaded-pin external fixation. The calcaneal plastic reduction forceps could effectively restore the calcaneal structure, with fewer complications than open reduction. The clinical effect was retrospectively evaluated, and the results support the practical superiority of this technique.

Clinical data

A total of 16 fresh unilateral calcaneal fractures from 2015 to 2017 were retrospectively analysed; there were 14 male and 2 female patients, and 4 and 12 fractures were on the left and right side, respectively. There were 10 cases of falling injury and 6 cases of traffic accident injury. The average patient age was 37.8 years (18–65 years). The mean follow-up time was 13.6 months (range, 12–15 months). Preoperative X-ray, thin-slice CT and three-dimensional reconstruction of the calcaneus were performed. According to the Sanders classification system[12], 4 fractures were classified as Sanders type I, 6 as Sanders type II, 4 as Sanders type III and 2 as Sanders type IV. Patients with closed, displaced intra-articular calcaneal fractures, open calcaneal fractures, a history of lower limb fracture or surgery, vascular disease or neurological complications were excluded. The calcaneal Bohler angle, Gissane angle and width were measured and recorded before and after the operation. The study was approved by the Ethics Committee of Zhongshan Hospital affiliated with Dalian University, and written informed consent was provided by the patients and their families.

Method

Operative technique

The patient was placed in a lateral position with the operative foot on the upper side. Calcaneal plastic reduction forceps were used for reduction under the guidance of C-arm fluoroscopy (*Fig 1,* calcaneal plastic reduction forceps). First, a 4.0 Kirschner wire was drilled vertically into the calcaneus and clamped in the groove of the calcaneal plastic reduction forceps. The surgeon holds the reduction forceps to the direction of the calcaneal nodules, and the assistant controls the rear of the lower leg and the forefoot to resist traction to restore the length of the calcaneus. At the same time, inversion of the calcaneus was corrected during traction; then, From the lateral side of the calcaneus, two fixation nails are screwed into the direction of the posterior joint of the posterior and posterior joints, two fixation nails are screwed into the ankle joint and the bone, and two fixation nails are screwed into the calcaneus nodules. Under fluoroscopy, the height of the talus was fixed by prying reduction according to the calcaneal height. The calcaneal plastic reduction forceps were used to squeeze the inner and outer walls of the calcaneus, restoring the width of the calcaneus and further correcting calcaneal varus. At this point, the length, width and height of the calcaneus were restored. The articular surface of the subtalar calcaneus was smooth, and moderate internal fixation was achieved. Five round, threaded pins were drilled into the distal and proximal ends of the calcaneus (*Fig 2,* threaded pins). Threaded pins with a self-tapping function can play a role in the compression and fixation of fractures. The pins were fixed with connecting rods and clamps (*Figs 3* and *4,* surgical procedures). Finally, the fracture position and internal fixation were reconfirmed by fluoroscopy.

Postoperative management

Antibiotics were routinely used once after the operation, and low-molecular-weight heparin was given for anticoagulation until 35 days after the operation. Foot elevation and elastic bandages were applied to help relieve swelling. The Kirschner wire root was bandaged daily with sterile alcohol gauze to prevent infection at the pinhole site. The patients were allowed to walk with two crutches on the second day after the operation but with no weight-bearing; partial weight-bearing was allowed at four weeks after the operation, and full weight-bearing was allowed at eight weeks after the operation. Active and passive activities of the ankle and hip joints were allowed immediately after the operation. On the first day after the operation, X-ray and CT imaging were performed postoperatively to ascertain the location of the fracture and Kirschner wire. Clinical and imaging follow-up examinations were performed 4, 8, 12, 6 and 12 months after the operation. The external fixator was removed in the clinic 6 weeks after the operation without anaesthesia. The calcaneal Bohler angle[13], Gissane angle[14] and width were measured 3 days and 6 months after the operation. The patients were evaluated according to the AOFAS score[15] at different follow-up times (6 months and 12 months after the operation) to evaluate pain relief and functional improvement during the follow-up period. According to this scale, a score of 90 to 100 points was considered excellent; a score of 80 to 89 points was considered good; a score of 70 to 79 points was considered moderate; and a score of less than 70 points was considered poor.

Statistical analysis

SPSS software (version 16.0) was used for the statistical analysis. Data are expressed as the mean (standard deviation). Single-factor ANOVA was used to compare data from before and after the operation. The SNK test was used to compare two means, and the significance level was a = 0.05.

Result

All operations were performed by the same surgeon; the average Bohler angle was 16.7° before the operation, 25.8° after correction, and 25.2° at the final follow-up. The average Gissane angle before and after the operation was 103.6° and 120.9°, respectively; the average angle at the final follow-up was 119.6°. The average width of the calcaneus before and after the operation was 39.5 mm and 35.2 mm, respectively; the average width at the final follow-up was 36.5 mm. The average height before and after the operation was 46.9 mm and 48.5 mm, and the average height at the final follow-up was 48.9 mm. The average length before and after the operation was 67.5 mm and 71.2 mm, respectively; the average length at the final follow-up was 70.9 mm (Table 1). The Bohler angle, Gissane angle, and calcaneal height, length and width were significantly improved at the last follow-up compared with preoperatively ($P < 0.05$), and while there was a slight decrease in these indicators at the last follow-up compared with postoperatively, there was no significant difference ($P > 0.05$) (*Fig 5)*..

The average AOFAS score was 60.1 at 6 months after the operation and 80.6 at 12 months after the operation; the average AOFAS score was significantly higher at 12 months than 6 months after the operation ($P < 0.001$). At the final follow-up, the AOFAS score was excellent, good, moderate, and poor in 11 cases, 3 cases, 1 case and 1 case, respectively. No complications occurred during or after the operation, and no cases of infection at the pinhole site or pin breakage occurred. All patients returned to work within 1 year after the operation, and no patients developed a walking disorder. Subtalar arthritis occurred in 2 of 16 patients.

Discussion

Calcaneal fractures account for 2% of all fractures, and 80% to 90% of these patients are young people[16]. The treatment of displaced intra-articular calcaneal fractures is still one of the most difficult problems in modern traumatology because of the complex shape of the calcaneus[17], the likelihood of comminuted fractures and the presence of unstable bone tissue. There is no clear evidence by which to determine the best treatment for intra-articular calcaneal fractures. Non-surgical treatment is suitable for patients with non-displaced calcaneal fractures. With the non-surgical treatment of displaced calcaneal fractures, patients with disability may not be able to return to their original jobs or may not even be able to work; thus, surgery is recommended for such patients[18]. The main purpose of surgical treatment is to restore the shape of the calcaneus to achieve anatomical reduction and reduce disability. However, surgery is not without the risk of complications. The rate of complications of the surgical treatment of trauma-related calcaneal fractures reportedly ranges from 7.57% to 32.8%, and the rate of neurovascular injury varies from 9.1% to 25%[19,20]. In a meta-analysis, Jiang et al.[21] confirmed that surgery could effectively restore the anatomical structure of the calcaneus in patients with displaced intra-articular calcaneal fractures and allow better functional recovery despite the high risk of complications.

Calcaneal fractures are usually caused by trauma and often involve the articular surface; these fractures can destroy the anatomical structure of the calcaneus and result in persistent pain, calcaneal varus deformity, and heel-fibula impact. If the treatment is not selected properly, the probability of disability and traumatic arthritis will increase, potentially leading to serious consequences in terms of weight-bearing and motor function[22]. Therefore, fractures involving the articular surface of the calcaneus should be actively treated by surgery to maximize anatomical reduction and restore the smoothness of the articular surface and the height, width and length of the calcaneus. Soft tissue damage is often associated with calcaneal fractures and is important to consider for accurate evaluation of the proper treatment of calcaneal fractures. Open reduction and internal fixation is a traditional surgical treatment method that has the advantages of a simple operation, full exposure, effective reduction and reliable fixation; however, this method also has the disadvantages of large surgical trauma and a high incidence incision-related complications after the operation. Because of the thin and fragile soft tissue around the calcaneus, the occurrence of wound-related complications after open reduction and internal plate fixation is a serious problem[23]. We used percutaneous fixation with Kirschner wire, wounds is small, less damage to blood supply, wet application of alcohol yarn around Kirschner wire, regular dressing change, no incision complications during follow-up, and extraction of Kirschner wire for 8 weeks, all The patient's incision heals well. The overall rate of wound healing problems after open reduction and internal fixation has been reported to be 16–25%, which is even higher than other previously reported values[24]. Most authors prefer to use a lateral L-shaped approach to fix calcaneal plates, and excellent results are achieved in 60–85% of cases treated with plate fixation; however, there is also a significant risk of soft tissue complications with this method[25]. Since 45% of the total blood supply of the lateral calcaneal wall enters from this side, the central and anterior parts of the lateral calcaneal wall are excised at the time of surgery[26]. Folk et al. reported the occurrence of 48 wound-related complications in 179 cases of calcaneal fractures treated surgically. Smoking, diabetes mellitus and open fractures are considered risk factors for such complications[27]. Deep infection can lead to chronic wounds or osteomyelitis, multiple operations and even amputation[28]. To avoid the extensive complications associated with the extended lateral approach, indirect or minimally invasive fixation techniques have been developed and applied in the treatment of calcaneal fractures[29]. Fernandez[30] and others have reported the successful application of minimal internal fixation, including closed reduction and percutaneous screw internal fixation.

The percutaneous external fixation technique is feasible for any type of intra-articular calcaneal fracture, especially for calcaneal fractures with severe soft tissue injury[31]. Tomesen et al.[32] reported that 78% of patients could wear shoes normally after closed reduction and percutaneous screw fixation. Corina[33] followed 128 patients (164 feet) for an average of 21 months; in these patients, the ankle and subtalar joints were mobilized immediately after the operation, and the external fixator was washed with saline twice a day after the operation. The results showed that there was no significant difference in the Maryland score or healing time among various calcaneal fractures. Forgon[34] reported on the treatment of 265 patients with minimally invasive percutaneous pin therapy alone; excellent results were achieved in 89% of the patients. Similarly, there are other minimally invasive techniques that achieve excellent functional outcomes. Mauffrey reported the treatment of displaced intra-articular calcaneal fractures with soft tissue defects using a fine wire external fixator[35].Polyzois et al.[36] used a circular external fixator in combination with a closed reduction or minimal approach and found that this surgical strategy was a good alternative for all calcaneal fractures. All patients in this study were treated with closed reduction using calcaneal reduction forceps combined with an external fixator. No complications involving the soft tissue or cases of pin-related infection occurred. When calcaneal fracture occurs, subcutaneous swelling reduction and haemostasis of the calcaneus require a long period of time; urgent operations can cause skin infection or necrosis, internal fixture-related infection and other complications. The proposed technique can also be used in patients with acute oedema and soft tissue injury. The additional advantage of minimally invasive surgery is that it greatly shortens the operative time and hospitalization time and reduces the risk of surgical complications.

Conclusion

This study confirms that the application of closed reduction using calcaneal plastic reduction forceps and external fixation can minimize the operative time and surgical complication rate. This method is simple and easy to learn. It has the following advantages: (1) it does not require extensive incisions or soft tissue dissection, and it does not easily cause skin necrosis or internal fixation-related infection; (2) the probability of significant deformity, traumatic arthritis and bone loss with this method is equivalent to that with conservative treatment[37] (percutaneous Stewart needle); (3) internal fixation can be removed with only local anaesthesia in the outpatient department and does not require a second operation, which reduces the financial burden on the patients; and (4) external fixation of the pin track is conducive to subcutaneous haematocele exudation, helping to prevent serious complications involving the skin and soft tissue. However, this study has some limitations. First, the cohort of this study was relatively small. Second, a longer follow-up time is needed to evaluate the potential development of subtalar arthritis. Finally, we performed the clinical and imaging measurements, and there was some deviation. In conclusion, the treatment of intra-articular calcaneal fractures using calcaneal plastic reduction forceps for closed reduction combined with external fixation has the advantages of causing minimal trauma, being easy to learn and having a low infection rate and thus has potential as a standard technique.

Declarations

Funding The funding agency had no input in to the design of the study, the collection,analysis and interpretation of data, the writing of the manuscript, or the decision to publish.

Conflict of interest The authors declare that they have no competing interests.

Informed consent No informed consent necessary, as study was retrospective.

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Table 1

Due to technical limitations, Table 1 is only available as a download in the supplemental files section.

Figures

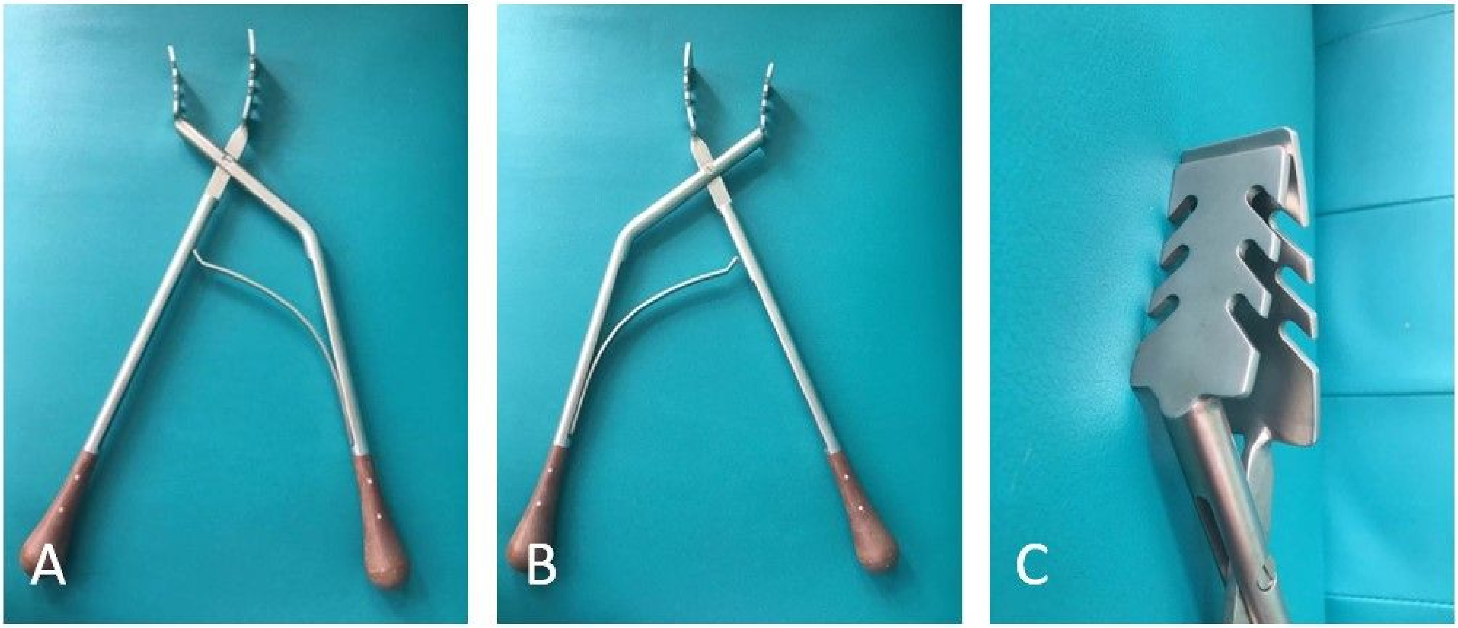

Figure 1

A, B. Calcaneal plastic reduction forceps are similar to the calcaneus in shape and structure. Simultaneously, the medial and lateral walls of the calcaneus are repositioned by compression to restore the calcaneal width. C. The oblique grooves on both sides of the calcaneal plastic reduction forceps are used to apply traction to the vertical Kirschner wires to restore the calcaneal length and correct valgus deformity.

Figure 2

A. Threaded calcaneal pins with self-tapping function applied after reduction. These pins can fix the calcaneus under pressure and are not easily loosened. The end of each pin is quadrilateral, which ABCABCD enables easy adjustment and removal using a wrench. B. The connecting rods and clamps link the threaded pins together to form an external fixator. C, D. T-shaped dismantling wrench.

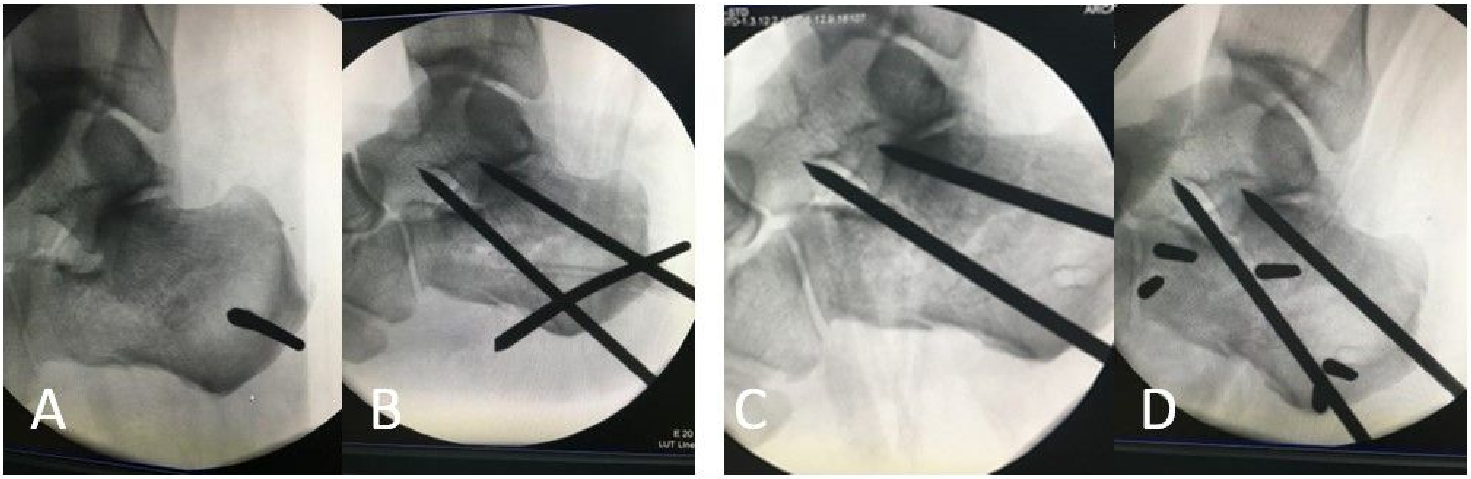

Figure 3

A. Vertical calcaneal drilling with a 4.0 Kirschner wire for restoring the calcaneal length. B. Calcaneal tubercle drilling with two 4.0 Kirschner wires longitudinally to restore the calcaneal height by prying. C. When the calcaneal height and length are restored, the vertical calcaneal Kirschner wire is pulled out, and the width of the calcaneus is restored by squeezing the internal and external walls with the calcaneal plastic reduction forceps. D. When the calcaneal shape is restored, five threaded pins are finally drilled in the lateral wall for fixation; C-arm fluoroscopy is used to assess the internal fixation and calcaneal position.

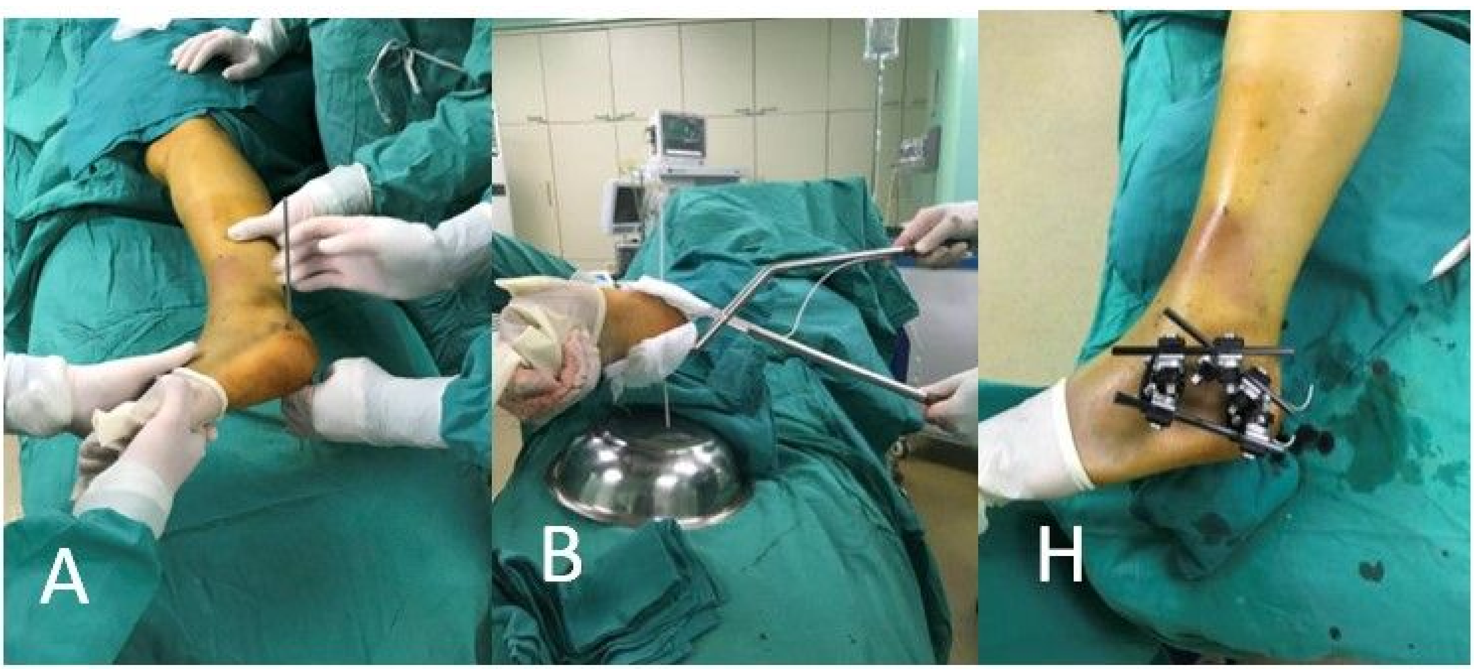

Figure 4

A. Acalcaneal pin is drilled vertically into the calcaneus, and the assistant applies opposing traction. B. The oblique grooves of the calcaneal plastic reduction forceps are used to clamp the calcaneal wires for reverse traction to restore the calcaneal length. H. Finally, the rods are connected and clamped for fixation.

Figure 5

A. Lateral and B. axial X-rays before the operation. C. Coronal CT scan showing Sanders type II calcaneal fracture. D. Transverse CT scan showing calcaneal nodule separation and displacement. E. Axial X-ray, F. lateral X-ray, and G, H. coronal CT scan showing good reduction of the subtalar articular surface and recovery of height and length. I. Coronal CT at 8 weeks after progressive weight-bearing; external fixator and threaded pins had been removed at 6 weeks. J. CT scan showing correction of the valgus angle, recovery of the length and width, and stability of the subtalar articular surface. K. Axial and L. lateral X-rays at the final follow-up showing good recovery of the calcaneus without traumatic arthritis.

Supplementary Files

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- Table1.jpg