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Review Article

Calcaneal reduction forceps for minimally invasive treatment of calcaneal fractures: literature review and techniques

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Abstract: Introduction: Calcaneal fractures are quite common. Due to the special anatomical structure of the calcaneus, treatment of these fractures is difficult and complicated. Although there are many different methods of treating calcaneal fractures, the best treatment method remains controversial. Conservative treatment of calcaneal sequelae will seriously affect future function. This scheme has proven to be inappropriate. The goal of surgical treatment is to restore the shape of the subtalar articular surface and the length, width, and height of the calcaneus. This could reduce the speed of articular cartilage wear and help patients recover a normal gait. Several surgical techniques are described in the current study. Open reduction and internal fixation have been widely described as gold standard methods. However, open reduction requires an extensive incision and dissection of the lateral skin and soft tissue. This can lead to many complications, such as skin necrosis, infections, and internal fixation failure. In response to these shortcomings, various minimally invasive techniques have been developed. The common goal is to be simple, effective, and inexpensive, potentially reducing the number of operations and complications, as well as length of hospital stays. Therefore, percutaneous minimally invasive treatment of calcaneal fractures has become increasingly popular among orthopedic surgeons in recent years. Many minimally invasive techniques have been described, including percutaneous external fixation, percutaneous reduction, percutaneous arthroscopy, and percutaneous expansion capsuloplasty. Although these minimally invasive techniques have achieved satisfactory results, none are perfect. The current study aimed to analyze minimally invasive techniques for treatment of calcaneal fractures and treatment of calcaneal fractures using calcaneal plastic reduction forceps combined with external fixation via percutaneous minimally invasive techniques.

Keywords: Calcaneal fracture, plastic reduction forceps, minimally invasive treatment, external fixator

Calcaneal fractures are the most common injury of the tarsal bone, accounting for 1-2% of all human fractures [1]. Recent studies have shown that 75% of foot function is affected by calcaneal fractures [2]. Calcaneal fractures are usually caused by high-energy trauma, with falling and traffic accidents as the most common causes. The shape of the fracture is determined by the position of the foot at the time of the fracture, quality of the bone, and the strength of the fracture. Approximately 75% of calcaneal fractures are intra-articular fractures involving the subtalar joint [3]. Calcaneal fracture patients are mostly young people engaging in heavy physical work. It is difficult for these people to return to their jobs a short time after the fracture, threatening their economic interests. For treatment of calcaneal fractures, there remains a controversy regarding the selection of conservative treatment or surgical treatment. There are several surgical treatment methods, but the effects vary. The main purpose of the operation is to restore the consistency of the subtalar joint, as well as the length, width, and height of the calcaneus. This will assist in returning to a normal lifestyle as soon as possible. Therefore, management of intra-articular calcaneal fractures is a challenge for any orthopedic surgeon [4].

The most common treatment for calcaneal fractures is open reduction and internal fixation via the lateral approach, the standard treatment for calcaneal fractures. However, this technique is not perfect and has been associated with some complications [5]. Because of the thin coverage of soft tissue on the lateral wall of the calcaneus, soft tissue injuries occur after fractures, along with swelling and blistering. In this case, open reduction and internal fixation is quite dangerous. Approximately 43% of patients have reported wound-related problems. The skin necrosis rate ranges from 2% to 11%, while 19.7% of patients develop superficial infections, 5.6% develop deep infections, and 1% develop osteomyelitis [6, 7]. It has been reported that the rate of wound-related complications is 25%, including infections in 1.3% to 7% of cases. Moreover, 21% of patients with complications need further surgery, according to a study of 190 calcaneal fracture cases reported by Folk et al. [8]. In addition, diabetes mellitus, smoking, surgical experience, and patient compliance may also affect wound healing [9]. Minimally invasive technology has been promoted and developed to avoid frequent and repeated problems after operations, ensuring good reduction and reduction of rates of complications. Such methods include percutaneous external fixation, percutaneous prying reduction, percutaneous arthroscopic-assisted technology, and percutaneous balloon angioplasty. One such technique, closed reduction or percutaneous reduction and external fixation can stabilize most displaced joint fractures. This greatly reduces the risk of open surgery via preoperative CT. Closed reduction or percutaneous reduction and external fixation is generally acceptable for open fractures. It has been included in many preliminary studies on the application of external fixation for calcaneal fractures [10]. Although the initial results of these techniques seem to be satisfactory, there is still little evidence indicating the best treatment option [11, 12].

The current study reports a minimally invasive technique for treatment of calcaneal fractures using calcaneal reduction forceps combined with external fixation and closed threaded pin prying reduction. This study describes experiences in calcaneal fracture treatment for orthopedic surgeons, ensuring that everyone can learn and improve together.

Minimally invasive treatment

Soft tissue wound-related complications have gained much attention, prompting many people to try to develop minimally invasive methods for treatment of calcaneal fractures. These techniques have become popular, recently, and are now widely used in all types of patients [13].

Percutaneous fixation

In cases of calcified fractures of the calcaneus or extensive soft tissue damage, percutaneous fixation is a good choice. External fixation can reduce tissue exposure, restore good heel bone volume and shape, and allow early weight bearing. There is still controversy regarding the priority for restoring either the articular surface of the calcaneus or the shape of the calcaneus. Dayton [14] showed that restoring the anatomy of the calcaneus is more important for restoring the function of the calcaneus. The main reasons are that recovery of the shape of the calcaneus will result in uneven force on the calcaneus, as well as impact the calcaneus inversion of the foot, among other factors. Studies have shown that early weight bearing after surgery may lead to better results and induce bone healing [15]. Pozo et al. [16] reported that weight bearing can lead to articular surface formation, which helps to restore the consistency of the subtalar joint. In addition, a significant advantage of the pinhole in percutaneous external fixation is that it can be used as a drainage point for the fracture site, thereby reducing local pressure. Additionally, percutaneous external fixation can prevent compartment syndrome within the first hour after trauma [17]. Forgon [18] reported outcomes of 265 patients treated with minimally invasive percutaneous screws. Results were excellent in 89% of the patients. Polyzois et al. [19] used a closed or circular approach with minimal invasiveness. They found this surgical strategy to be a good alternative for all calcaneal fractures. Percutaneous external fixation is feasible for any type of intra-articular calcaneal fracture, especially in patients with calcaneal fractures and severe soft tissue injuries [20]. Begue [21] suggested the use of external fixation in emergent cases, with the priority being to restore the length, width, height, and varus of the calcaneus, prompting the basic anatomy of the calcaneus and soft tissue to return to normal as soon as possible. Based on this, if posterior articular surface reduction is not satisfactory, other minimally invasive fixation methods can still be performed in the future. He studied 20 cases of various complex calcaneal fractures, 11 of which were two fractures (fixed with screws, plates, and Kirschner wires), with no cases of pinhole infections. Final outcomes in 3 cases were poor and joint fusion was required. The other outcomes were good. Walde used traction and percutaneous fixation to treat 67 patients with calcaneal fractures, with an average follow-up duration of 5.7 years. In all, 70.1% of the patients recovered the Bohler angle and 77.7% had good results. The complication rate was 6.5% [22].

Percutaneous prying reduction

Percutaneous reduction is performed by inserting the Kirschner wire along the long axis of the calcaneus at the calcaneal nodule, reaching the obvious area of the fracture. The use of Kirschner wires for extraction and the basic recovery of the calcaneal Bohler angle is a basic means of percutaneous reduction for treatment of calcaneal fractures. The classic Essex-Lopresti method involves placing a large Kirschner wire axially into the bone to restore the collapse of the articular surface, Bohler angle, Gissane angle, and the internal and external calcaneal configuration by sacral retraction. Currently, ordinary Kirschner wires, threaded Kirschner wires, hollow nails, and lag screws, among other fixation materials, are commonly used. For Sanders type III and comminuted Sanders type IV fractures with severe subsidence of the subtalar articular surface, it is difficult to pry and reposition the posterior calcaneal articular surface. This could lead to reduced hindfoot function [23]. Repeated prying and comminution of fractures will further aggravate fragmentation of the fracture fragments. In this way, improved prying and repositioning methods will be beneficial for Sanders type III and Sanders type IV fractures. Good effects have been reported [24]. There were no significant differences in the reduction or AFOAS functional scores among fracture types. Calcaneal prying methods are also constantly being improved, reducing complication rates. At present, the improved prying techniques are more practical. Abdelgaid [25] reported 60 patients with calcaneal fractures treated using an improved prying reduction method. The rate of excellent and good AFOAS scores was 79.3%. No wound infections occurred. In 3 cases, reduction was lost due to premature load bearing, while the remaining functions were good. With minimally invasive treatment, earlier treatment leads to more favorable outcomes. Rammelt [26] reported that earlier operations led to more favorable percutaneous anatomical reduction. With longer times to treatment, more scar formation occurs around the fractures. This increases the difficulty of reduction.

Percutaneous arthroscopic adjuvant therapy

It is difficult to reset the posterior articular surface of the calcaneus by traditional prying reduction. This method can be used to reset the articular surface accurately and remove the fragments and hematoma of small fractures in the articular cavity. An adjuvant technique for arthroscopy is closed prying under arthroscopic surveillance. Rammelt proposed the reduction of the posterior calcaneal articular surface by subtalar arthroscopy in 1997. In 2002, Sanders type I and type II fractures were treated for the first time with arthroscopic-assisted percutaneous reduction and screw fixation. Sixteen patients with calcaneal fractures were treated with arthroscopic-assisted closed reduction and screw fixation. No patients reported wound-related complications or pain after the operation. AOFAS scores averaged 9.4 points [27]. Woon conducted a prospective study of 22 patients with calcaneal fractures. In these patients, no complications or infections were found at the 2-year follow-up visit. The Bohler angle was corrected well and the AOFAS score was 84.2 [28]. Thirty-nine patients with Sanders type II and type III calcaneal fractures were treated by Pastides [29] under percutaneous arthroscopy. The average follow-up period was 24 months. The average Bohler angle and AOFAS score was 23.41 and 72.18, respectively. Of these, 1 patient developed a superficial infection and 2 patients experienced screw withdrawal. There were no cases of deep infections and no need for joint fusion. The average hospital stay was only 1.92 days. Arthroscopy has its drawbacks, such as the small subtalar joint space and ease of damaging the articular cartilage.

Balloon dilatation

In recent years, the method of percutaneous balloon reduction and cement injections for treatment of calcaneal fractures has been reported [30]. This method is based on percutaneous vertebroplasty [31]. Balloon dilatation for treatment of calcaneal fractures was first proposed

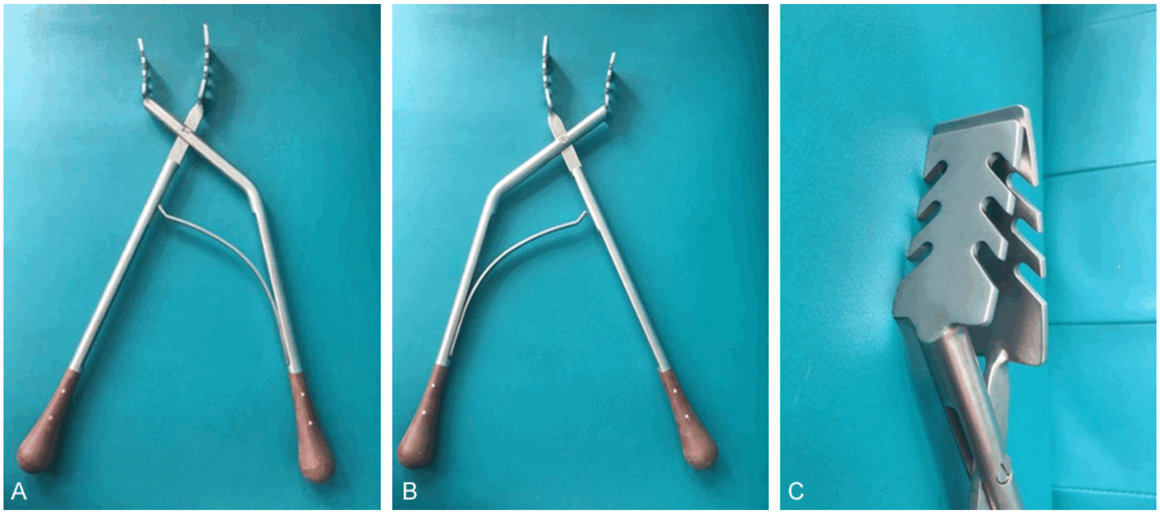

Figure 1. A. Calcaneal plastic reduction forceps are similar in shape to the human calcaneal arc and can be used on the calcaneus; B. Extrusion reduction was performed on the lateral wall; C. The lateral groove was used to hold the Kirschner wire for traction to restore the calcaneal length and correct valgus.

by Bano [32] in 2009, based on prying reduction. In the treatment of calcaneal fractures, the guide needle is inserted into the calcaneal body and the balloon dilator is then inserted into the guide needle. The fracture is then reduced through balloon dilatation. At the time of expansion, the two sides of the calcaneus are compressed by both hands to restore the height and width of the calcaneus. Jacquot [33] used balloon dilatation to treat 11 patients with calcaneal fractures, of which 5 were Sanders II and 6 were Sanders III. After 3-5 years of follow-ups, the rate of excellent and good AOFAS scores was 81.8%. There were no complications or wound-related infections, except for 1 case of subtalar arthritis and arthrodesis and one case of retirement. The remaining patients recovered to preinjury working statuses. The authors concluded that it is better to restore first, then inject bone cement. Chen [34] et al. suggested that prying reduction should be performed first, followed by balloon dilatation reduction. Comparisons between balloon dilatation combined with cannulated screw fixation (38 cases) and open reduction and internal fixation (40 cases) showed that there were no significant differences in postoperative complications, Bohler angles, or calcaneal shape reduction. There were no significant differences in operative times, blood loss, postoperative joint mobility, AFOAS scores, or Maryland foot scores. The average score was superior to that of open reduction and internal fixation. The sample size for balloon dilatation was small. Further research is necessary to determine whether the cement leaks into the subtalar joint space, resulting in joint surface wear and limited joint mobility.

Our method

The current study retrospectively analyzed 16 cases of unilateral calcaneal fractures treated with calcaneal plastic reduction forceps combined with external fixation via a minimally invasive technique.

Surgical techniques

The patient was placed in a lateral position with the injured foot on the upper side. Calcaneal plastic reduction forceps were used for reduction under C-arm fluoroscopy guidance. **Figure 1** shows the shape of the 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 length of the calcaneus was restored by opposing traction applied by the assistant. At the same time, the calcaneal varus was corrected by traction. The Kirschner wire was drilled into the calcaneal tubercle behind the calcaneal tubercle. Under fluoroscopy, the height of the calcaneus was fixed to the talus using prying reduction forceps. Calcaneal plastic reduction forceps corrected the calcaneal varus. Fluoroscopy proved that calca-

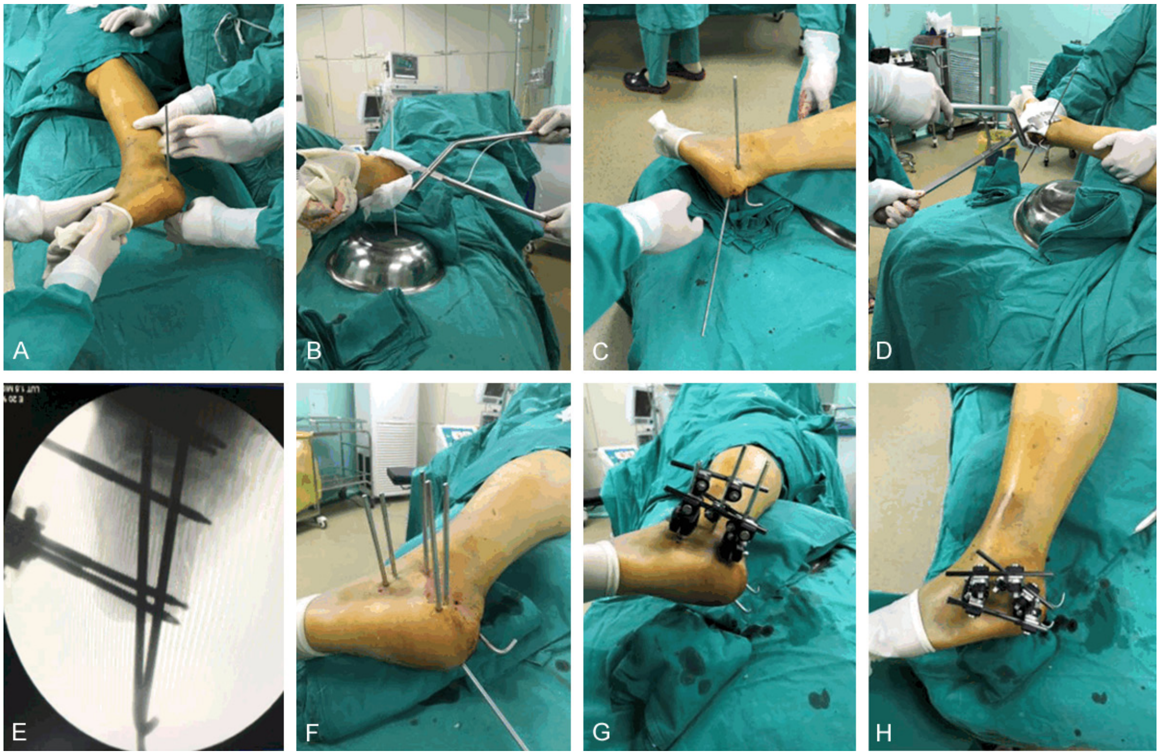

Figure 2. A. Calcaneal pin is drilled vertically into the calcaneus. The assistant applies opposing traction. Calcaneal plastic reduction forceps and oblique grooves are used to block the retrograde traction of the Kirschner pin; B. Restoration of the calcaneal length; C. When the length is restored, two Kirschner pins are drilled into the calcaneal tubercle and used to restore the calcaneal height by prying; D. Calcaneal reduction forceps are aligned with the calcaneal arc and the inner and outer arms are extruded to restore the calcaneal width; E, F. Internal and external positions of the screw pin confirmed by fluoroscopy; G, H. Finally, the connecting rods and clamps were fixed.

neal lengths, widths, and heights were restored. The subtalar articular surface was smooth and the internal fixation force was moderate. Five threaded bone pins were drilled into the distal and proximal ends of the calcaneus. The threaded pins, with a self-tapping function, could play a role in compression and fixation of the fracture. Connecting rods and clamps were used to fix the fracture. **Figure 2** show the operation steps. Finally, the fracture and internal fixation position were confirmed by fluoroscopy again. Active and passive movement of the foot and ankle joints began after the operation. Six weeks after the operation, outpatient radiographs were reviewed. The external fixator was removed (**Figure 3**). Eight weeks after the operation, weight-bearing walking was gradually performed.

Patients

Sixteen cases of unilateral displaced intra-articular calcaneal fractures were retrospectively analyzed. The average age of the patients was 37.8 years (18-65 years). Lateral and axial X-ray films, thin-slice CT scans, and three-dimensional reconstructions of the calcaneus were obtained before the operation. According to the Sanders classification, 12 cases of calcaneal fractures were classified. There were 4 cases of Sanders type I, 6 cases of Sanders type II, 4 cases of Sanders type III, and 2 cases of Sanders type IV fractures. There were 10 cases of falling injuries and 6 cases of traffic accidents. Bohler angles and Gissane angles were measured before and after treatment and at the end of the follow-up period. AOFAS scores were used to evaluate functional outcomes. The mean follow-up time was 13.6 months (range, 12-15 months). The average Bohler angle was 16.7, 25.8, and 25.2 at these time points, respectively. The preoperative Gissane angle was 103.6. The average postoperative angle was 120.9 and the angle at the final follow-up was 119.6, with only a few degrees of settling or loss. The average AOFAS score was 80.6 at the end of the follow-up period. Of the final follow-up AOFAS scores, 11 were excellent,

Figure 3. (A) Lateral X-ray film (B) of the patient 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 scans showing good reduction of the subtalar articular surface and recovery of the height and length. The external fixator and threaded pins were removed at 6 weeks; (I) Re-examination by coronal CT after 8 weeks of progressive weight-bearing showed that the inversion angle was corrected, the lengths and (J) widths were recovered, and the subtalar articular surface was smooth; (K) Axial X-ray at the last follow-up; (L) The calcaneus recovered well and no traumatic arthritis occurred.

3 were good, 1 was medium, and 1 was poor. No complications occurred during or after the operation and no cases of pinhole infections or pin breakage occurred. All patients returned to work within 1 year after the operation and no cases of walking disorders were found. Subtalar arthritis occurred in only 2 of 16 patients.

Conclusion

Percutaneous minimally invasive treatment of calcaneal fractures can achieve approximate anatomical reduction of the calcaneus [35], maintain the activity of the subtalar joint, reduce tissue edema and scar formation around the joint, avoid joint stiffness after the operation, and reduce incidence of wound infections, fractures of internal fixator components, and other complications. The shape of the calcaneal plastic reduction forceps we designed is similar to that of medial and lateral calcaneal walls. These forceps can be applied to the bilateral calcaneus. Present researchers combined several minimally invasive techniques, such as calcaneal prying, percutaneous treatment, and external fixation. Based on closed calcaneal prying reduction, this study used oblique grooves on the sides of the calcaneal plastic reduction forceps to clamp the axial calcaneal Kirschner pin and restore the calcaneal length against opposing traction. At the same time, the width of the calcaneus can be restored by pressing the medial and lateral walls of the calcaneus and the valgus. Finally, the external fixator can be used to further stabilize the reduction. During the final follow-up period, 2 cases of subtalar arthritis occurred, potentially caused by the rougher articular surface. Although most of these patients achieved satisfactory results, prospective studies with larger cohorts and longer follow-up times are necessary to better evaluate the disadvantages and advantages of these techniques. In other words, minimally invasive techniques are the general trend of all fracture treatments. With improvements in technology, mastering and utilizing the minimally invasive method of percutaneous treatment will certainly improve the clinical efficacy of treatment for calcaneal fractures.

Disclosure of conflict of interest

None.

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