Original research

A minimally invasive sinus tarsi approach with percutaneous plate and screw fixation for intra-articular calcaneal fractures

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A B S T R A C T

According to characteristic of anatomical structure of calcaneus and sinus tarsi approach, the minimally invasive plate for treatment of displaced intra-articular calcaneal fractures had been designed. Here we aimed to review the effect of this treatment. Forty intra-articular calcaneal fractures in 38 patients from September 2006 to September 2008 were treated with percutaneous plate via sinus tarsi approach under the monitoring of C-shaped arms. All calcaneal anatomical parameters, including height, width, length, Böhlers angle and Gissane angle were measured by X-ray before and after surgery. Postoperative lateral wound healing was also evaluated and clinical functional outcomes were graded using the Maryland foot score. All patients had been followed up for an average of 12 months ranged from 3 months to 24 months. X-ray indicated satisfactory restoration of the calcaneal height, width, length, Böhlers angle and Gissane angle. Maryland foot score demonstrated that excellent result was achieved in 32 cases, good in 6 cases, fair in 2 cases, and the excellent and good rate was 95%. Postoperative complications were not found in all fractured feet. Our results suggest that this minimally invasive sinus tarsi approach with new designed plate and screw fixation technique for the treatment of intra-articular calcaneal fractures can not only obtain the satisfactory outcomes, but also can effectively prevent surgical complications.

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1. Introduction

Calcaneal fractures are the most common fracture of the tarsal bones, yet the treatment approach has always been the challenge in clinical research of orthopedics.1,2 Most surgeons have favored non-operative treatment of these fractures in the past, however, it is hard to obtain excellent anatomical reduction, especially for displaced calcaneal fractures. What’s more, other problems also occur including loss of calcaneal height, increased calcaneal width and uneven articular surface, leading to calcaneal malunion and traumatic arthritis, severe enough to influence walk, stand and jump function.2,3 Since the mid 1990s, open reduction internal fixation has been considered as the gold standard surgery treatment for displaced intra-articular fractures of the calcaneus by most experts, by which benefits in anatomical reduction, restoration of subtalar joint congruity, calcaneal height, width and decreased lateral impingement are available compared with the non-operative treatment.4,5 Several open surgical techniques have been described, of which the extensile lateral L-shaped approach has been applied most frequently. However, postoperative wound complications, including wound edge necrosis, dehiscence, hema-toma, or deep infection remain a major concern.5,7

To lower the wound complications, several minimally invasive procedures have recently been introduced. Closed reduction and percutaneous screws fixation is a widely reported minimally invasive surgical treatment in the literature to date, which can effectively avoid wound complications due to the small incision.8–10 However, this method seems to be more suitable for these cases with more complete calcaneal fracture fragments and moderately displaced fracture because of the limited screw fixation strength.11,12 Thus, combined plate fixation is advocated.13

In addition, a modified lateral approach (minimally invasive sinus tarsi approach) is also recommended for treatment of displaced calcaneal fractures. This incision begins at the tip of the lateral malleolus and is extended toward the base of the fourth metatarsal which allows the access to the sinus tarsi, to subtalar joint and to the vision of joint facets.14,15 Holmes and Hospodar have achieved calcaneus intra-articular fractures reduction and percutaneous screws fixation by this incision, and obtained the desired outcomes without any wound complications. The obvious advantages of the approach lie in the simple operation to reset
Fig. 1. Percutaneously inserted calcaneal plate with two arms and one body at an angulation for solid triangle fixation.

subtalar articulation, so that it decreases the impact on local skin blood supply, shortens significantly operation time and reduces incidence of postoperative complications. However, it is not ignored that the lateral wall of calcaneus cannot be fully exposed via this small incision and the application of common calcaneal plate is limited.

In this study, we developed a new minimally invasive percutaneous insert plate according to the characteristics of anatomical structure of calcaneus and sinus tarsi approach. The primary aim of this study was to assess the functional outcome of the percutaneous screws and plate fixation of displaced intra-articular calcaneus fractures via sinus tarsi approach.

2. Materials and methods

2.1. Special plate design

The plate was used specifically for type II and type III fractures of Sanders classification system (patent number: ZL 2007 2 0076532.9). The plate was made of Titanium alloy, with the structure of two arms and one body. There are two round screw holes in forearm, 3 in rear arm, and 4–5 in the body to respectively fix the anterior process of calcaneus, calcaneal body, bones below subtalar joint surface and bones behind calcaneus body (Fig. 1). The plate, 1.5 mm in thickness and 12 mm in width, can bear 1819 ± 65.7 N in vertical maximum load-bearing capacity and 122.8 ± 4.9 N in the greatest resistance to bending loads (measured by Biomechanics Laboratory, Shanghai Jiaotong University Affiliated Ninth People’s Hospital). There is no significant difference in vertical maximum load-bearing capacity between common calcaneal plate (2920 ± 252 N) and our minimally invasive plate (2656 ± 214 N) in artificial calcaneal fracture model (Engineering Mechanics Experiment Center, Shanghai Jiaotong University).

2.2. Patients

From September 2006 to September 2008, 40 intra-articular calcaneus fractures in 38 patients were surgically treated in our hospital. The indication for surgical treatment was a decrease in the height and an increase in the width of normal calcaneus, reduced Böhler angle and Gissane angle. Among the 38 patients included in this study, 37 were males and 1 was female. Their average age was 42 years old (between 18 and 58). Injury mechanisms were a fall or jump from a height in 37 cases and traffic accident in 1 case. All cases were closed fractures with unilateral involved in 36 cases and bilateral involved in 2 cases. In addition, three cases had associated injuries of the lumbar spine fracture and one case of tibia fracture. Ten cases had more than five-year tobacco history who were instructed to stop smoking until complete wound healing while two cases were diabetic which was controlled. All patients received anteroposterior, lateral and axial X-ray radiography (Fig. 2A and B) and horizontal and coronal computed tomography (CT) scan (Fig. 3A and B) of the fractured calcaneus preoperatively. According to Sanders classification system, there are 22 feet of type II fractures (6 type IIa, 14 type IIb, 2 type IIc) and 18 feet of type III fractures (7 type IIIa, 10 type IIIb, 1 type IIIc). The time from injury to surgery has been from 7 to 11 days with an average of 8.3 days. All patients underwent the percutaneous plate and screw fixation via sinus tarsi approach for treatment of intra-articular calcaneus fractures by the first author. The study protocol was approved by the responsible local ethics committee and written informed consent was obtained from all participants.

2.3. Surgical procedure

After admission, the extremities of patients were elevated and ice applied in an effort to minimize swelling and avoid blisters. All patients underwent spinal subarachnoid block analgesia or epidural anesthesia and were placed in a supine position for two feet treatment or in a lateral decubitus position for one foot treatment. The lateral incision of calcaneus was made via sinus tarsi approach beginning from the anterolateral corner of the tip of the lateral malleolus, through sinus tarsi, calcaneocuboid joint and extending to the proximal cuboid. The front incision was directed toward lateral wall bone of anterior process of calcaneus. Using sharp dissection, this incision was carried down to the posterior subtalar joint capsule. Care was taken to protect the lateral sural cutaneous nerve, peroneus longus and brevis tendon. According to the observed lateral buckling of the lateral wall and displacement of subtalar articular surface, we elevated the subtalar articular surface with a dedicated elevator inserting into the fracture and then a 3.5 mm Steinmann pin was inserted into the calcaneus tuberosity followed by longitudinally extending to the posterior articular surface to correct the Böhler angle. After reduction, the Steinmann pin was driven into the anterior process of calcaneus. Allograft bone was used to fill the large defect that remained after the reduction. After the calcaneus length, height and width, and Böhlers and Gissanes angle was recovered satisfactorily under C-arm fluoroscopy, the plate was inserted to the front from the rear incision up to anterior process of calcaneus by percutaneous calcaneus lateral channel (Fig. 2C and D). Screws were applied in rear of the calcaneal body, subtalar articular surface and anterior process of the calcaneus, and an additional compression screw was directed toward the sustentaculum tali. Following the plate and screw were well fixed under C-arm fluoroscopy, the rubber drains were inserted into the anterior and posterior incision, and the incision was closed in a layered fashion followed by compression bandaging.

2.4. Postoperative management

Postoperatively, the affected limbs of patients were elevated to minimize swelling and immobilized by plaster cast. Since day 2, it is possible to begin passive and active motion without weight bearing of fibio-tarsic joint and isometric exercise for lower limb muscle. Rubber drainage was extracted after 48 h, and incision was cleaned every two days until sutures were removed approximately 2 weeks after surgery (Fig. 2E). Plaster was removed after three weeks and weight bearing was initiated after 3 months. Radiographs were taken preoperatively and postoperatively to measure the calcaneal anatomical parameters, including height, width, length, Böhler angle and Gissane angle. Clinical functional outcomes were graded using the Maryland foot score.

2.5. Statistical methods

All data were analyzed by SPSS 12.0 statistical software and expressed as mean ± standard deviation (SD). The preoperative and postoperative calcaneal anatomical parameters were compared by
Fig. 2. Preoperative lateral X-ray shows reduced calcaneal height, significantly reduced Böhler angle and Gissane angle (A); preoperative axis X-ray shows an apparent increase in calcaneal width (B); The plate is inserted from the rear incision to the front along the right lateral wall of the calcaneus (C); and placed in the lateral calcaneal channel after its establishment (D); at 14 days after surgery, the incision heals, the stitches are removed, no skin or soft tissue infection and necrosis are observed (E); Postoperative calcaneus lateral radiograph shows anatomical reduction of the subtalar articular surface, significant correction of calcaneal height, Böhler angle and Gissane angle (F); postoperative calcaneal axial radiograph shows satisfactory recovery in calcaneus width (G); During 3 months follow up after surgery, the calcaneus lateral radiograph shows the disappeared fracture line, even subtalar articular surface, and no obvious lost in calcaneal height, the Böhler angle and Gissane angle correction (H); postoperative calcaneus radiograph shows no obvious lost in calcaneal width correction (I).

Fig. 3. Preoperative calcaneal coronal CT scan shows two fracture lines divide articular surface into three-part widened fractures (A); Preoperative calcaneal level CT scan shows the crushed calcaneus fracture fragment with a bulking lateral wall (B).
paired t-test. Comparisons were considered to be significant at \( p < 0.05 \).

3. Results

All patients had been followed up for an average of 12 months ranged from 3 months to 24 months. Postoperative X-ray showed satisfactory results of calcaneal fracture reduction, the calcaneal height, width, length, Böhler angle and Gissane angle were fully corrected (Fig. 2F–I). Further statistical analysis indicated that each anatomical parameter was significantly restored 3 months after operation and at the last follow up (all \( p < 0.01 \) (Table 1)). In addition, no screw loosening, screw or plate breakage was observed during the follow-up. According to Maryland foot score, 32 fractures resulted excellent (90–100 points), six good (75–89 points), and two fair (50–74 points), with excellent/good rate of 95% (38/40). Among all cases, no one developed the poor wound healing, secondary infection and other complications.

4. Discussion

Given the limited strength of the simple screw fixation, we develop a minimally invasive calcaneus plate that can be inserted through the sinus tarsi incision. The arch structure of plate can mimic the similar arc shape of calcaneus with two short arms front and back and a long body in the middle at an angle. Forearm with two holes can be used for fixing the anterior process of calcaneus, rear arm with three holes for the rear calcaneus, and the body with 4–5 holes for the body of the calcaneus. The protrude screw hole was used for the support of fractured fragments below the posterior articular surface. Thus, the solid triangle support is formed by front, central and rear screw fixation. As expected, no screw loosening, screw or plate breakage was observed during the follow-up. Compared with the common calcaneus plate, as cervical H plates, reconstruction plate, multihole plates, our plate possess simple structure, small size, and perfect morphology match with lateral calcaneus, which may not only provide adequate strength to support fractured calcaneus [no significant difference in vertical maximum load-bearing capacity compared with common calcaneal plate (2520 ± 252 N)], but also reduce the tension of skin and soft tissues and contribute to easy insertion and extraction via the channel between peroneal tendon and the lateral wall of calcaneus due to less space occupation. Therefore, good treatment results were obtained in 95% of the fractured calcaneus, with a significant restoration of calcaneal height, width, length, Böhler angle and Gissane angle, as well as no postoperative wound complications. In addition to the new minimally invasive calcaneus plate, our excellent results may also be attributable to the sinus tarsi approach, which has been demonstrated to be effective for decreasing risk of acute or secondary post-operative complications, as infections or hardware failure.

Previously, studies have used the percutaneous screws and plate fixation through the sinus tarsi for treatment of Sanders type II and III calcaneal fractures, the overall satisfactory results (excellent and good) seems to be lower than our results.5 This further confirms the advantage of our plate which provides the stronger fixation strength than the limited screw or common plate.6

However, there are still some limitations in this technique. This minimally invasive sinus tarsi approach with new designed plate and screw fixation technique is still difficult for exposure and restoration of fractured fragments of the medial wall of the calcaneus and the calcaneus below; The fewer screws are not enough for rigid fixation of crushed calcaneal fractures; Further investigation with large sample size and longer follow-up time is still needed to obtain a more precise clinical efficacy.

Ethical approval

None.

Funding

None declared.

Author contribution

Xia Shengli and Wang Xiuhui participated in the design of this study, and they both performed the statistical analysis. Lu Yaogang carried out the study, together with Wang Huizhong, collected important background information, and drafted the manuscript. Wu Zuming and Wang Ziping conceived of this study, and participated in the design and helped to draft the manuscript. All authors read and approved the final manuscript.

Conflict of interest

We have no conflicts of interest to state. All the parts including research, manuscript and abstract are original and aren’t presented in any form before.

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References


Table 1

Radiological results before and after operation.

<table>
<thead>
<tr>
<th>Group</th>
<th>Böhler angle(°)</th>
<th>Gissane angle(°)</th>
<th>Calcaneal height(mm)</th>
<th>Calcaneal width(mm)</th>
<th>Calcaneal length(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operation</td>
<td>1.8 ± 4.3</td>
<td>95.1 ± 5.5</td>
<td>33.3 ± 2.1</td>
<td>39.8 ± 1.9</td>
<td>65.0 ± 1.6</td>
</tr>
<tr>
<td>3 months post-operation</td>
<td>28.6 ± 3.3°</td>
<td>120.0 ± 5.7°</td>
<td>38.3 ± 1.3°</td>
<td>33.1 ± 1.7°</td>
<td>68.4 ± 1.4°</td>
</tr>
<tr>
<td>Last follow up</td>
<td>28.4 ± 3.1°</td>
<td>119.7 ± 5.2°</td>
<td>38.2 ± 1.7°</td>
<td>33.3 ± 1.6°</td>
<td>68.3 ± 1.4°</td>
</tr>
</tbody>
</table>

\(^{*}p < 0.01\) Compared with pre-operation. There was no statistical difference between 3 months post-operation and last follow up.