Minimally invasive reduction of the medial wall shortening and misalignment in calcaneal fractures with intraoperative percutaneous traction using an external fixator

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Abstract: Objective: To evaluate the outcomes of the application of intraoperative percutaneous traction using an external fixator for the reduction of medial wall shortening and misalignment in calcaneal fractures. Methods: From December 2011 to December 2013, 23 Sanders type III or type IV calcaneal fractures with medial wall shortening and misalignment in 22 patients were reduced with open reduction and internal fixation combined with intraoperative percutaneous traction. Bohler’s angle, Gissane’s angle, calcaneal height and calcaneal width were measured before surgery, after reduction with common technique and after reduction with the external fixator, respectively. At every follow-up visit, clinical outcomes were evaluated by the Maryland Foot Score. Results: Bohler’s angle, Gissane’s angle, calcaneal height and calcaneal width were improved after reduction with common technique (P < 0.05). Whereas, reduction with the external fixator improved Bohler’s angle, Gissane’s angle and calcaneal width further compared with reduction with common technique (P < 0.05). During the follow-up period, associate soft tissue-related complications were observed in one case. At the final follow-up visit, clinical outcomes of eleven of thirteen Sanders type III fractures (84.62%) and eight of ten Sanders type IV fractures (80%) were considered excellent or good according to the Maryland Foot Score. Conclusion: Intraoperative percutaneous traction using an external fixator represents a safe and effective method for the reduction of medial wall shortening and misalignment that cannot be well reduced through the lateral approach. The combined use of intraoperative percutaneous traction and open reduction and internal fixation through the extended lateral approach for complex displaced intra-articular calcaneal fractures ensures desirable clinical outcomes.

Keywords: Calcaneal fractures, medial wall shortening, open reduction, internal fixation, external fixation, intraoperative traction

Introduction

Since the mid-1990s, open reduction and internal fixation (ORIF) has been considered as the gold standard for the treatment of calcaneal fractures that are hardly reduced by less invasive methods [1-7]. Several approaches have been described in the past, of which the extended L-shaped lateral approach has been applied most frequently [8-12]. This approach allows surgeons to visualize and reconstruct the destroyed lateral wall, the posterior facet of subtalar joint, and the calcaneocuboidal joint. However, residual hind-foot varus may exist after ORIF through the extended lateral approach due to the inability to reduce the medial wall shortening and misalignment, which are not rare in complex displaced intra-articular calcaneal fractures, through this approach [13, 14].

To overcome these problems, the combined use of lateral and medial approaches has been introduced to achieve accurate reduction of both walls of calcaneus [15]. However, they suffer from associated soft tissue-related compli-
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Minimally invasive techniques might diminish the incidence of soft tissue-related complications, whereas, using these techniques alone may carry the risk of incomplete reduction [16]. Although using minimally invasive techniques alone is challenging for the treatment of complex displaced intra-articular calcaneal fractures, these techniques could serve as supplements to ORIF through the extended lateral approach to aid in medial wall reduction.

Hence, we used intraoperative percutaneous traction with an external fixator to improve the reduction of the medial wall in the treatment of complex displaced intra-articular calcaneal fractures with ORIF through the extended lateral approach. The aim of current study was to evaluate the outcomes of this method.

Materials and methods

Patients

This study was in adherence with the Declaration of Helsinki. Independent Ethics Committee of the Affiliated Sixth People’s Hospital of Shanghai Jiao Tong University approved the protocols of this study. Written informed consent was obtained from each patient.

From December 2011 to December 2013, twenty-three closed complex displaced intra-articular calcaneal fractures with the medial wall shortening and misalignment (Figure 1A-D) in twenty-two patients were treated with ORIF combined with intraoperative percutaneous traction as consecutive cases by the same operator (JS). Six additional patients unwilling to attend the study or failed to follow-up were excluded.

Surgical technique

Patient was placed on the fracture table in a prone position. The extended L-shaped lateral approach was made as described elsewhere [9]. Subperiosteal dissection was performed to expose the lateral wall, and a full-thickness soft tissue was created. Three 2.0 mm K-wires were placed in fibula, talus, and cuboid for flap retraction with avoiding any further handling of...
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Table 1. Radiological results (mean ± standard deviation, n=23)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Bohler’s angle (degrees)</th>
<th>Gissane’s angle (degrees)</th>
<th>Calcaneal height (mm)</th>
<th>Calcaneal width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before surgery</td>
<td>7.33 ± 6.52</td>
<td>106.05 ± 10.19</td>
<td>53.44 ± 5.16</td>
<td>50.71 ± 5.20</td>
</tr>
<tr>
<td>After reduction with common technique</td>
<td>14.93 ± 7.26*</td>
<td>113.37 ± 10.26*</td>
<td>57.05 ± 5.26*</td>
<td>41.70 ± 4.63*</td>
</tr>
<tr>
<td>After reduction with the external fixator</td>
<td>26.17 ± 4.66**</td>
<td>127.96 ± 6.07***</td>
<td>60.04 ± 5.65**</td>
<td>37.99 ± 3.30***</td>
</tr>
<tr>
<td>F value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
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<tr>
<td>P value</td>
<td></td>
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</tbody>
</table>

The asterisks indicate significant differences between time points on ANOVA and with use of the SNK post-hoc test for multiple comparisons: *P < 0.05 compared with before surgery; **P < 0.05 compared with reduction with common technique.

the flap. The lateral wall was removed and stored in normal saline. A 3.5 mm Steinmann pin was inserted from the superoposterior portion of calcaneal tuberosity into fracture fragment along its axis. A longitudinal traction and a varus tilt were then performed with the Steinmann pin to reduce the posterior articular facet. Reduction of calcaneal width was achieved by placing a longitudinal traction and a valgus tilt on the Steinmann pin while compressing both walls of the calcaneus manually. The reduction was stabilized with two 2.0 mm K-wires and checked under intraoperative X-ray.

If the medial wall was not well reduced even after repeated reduction attempts using the common technique mentioned above (Figure 1E), an external fixator would be applied (Figure 1F). Two 4.0 mm half pins were respectively placed in talus and calcaneal tuberosity medially. A unilateral external fixator (Carefix, Shanghai, China) was used to connect the half pins. A longitudinal traction was performed with the external fixator to reduce the width, height and varus of the calcaneus. Simultaneously, a periosteum detacher was inserted through the lateral approach to facilitate reduction. After the reduction was achieved (Figure 1G), allogenic bone graft (Aorui, Shanxi, China) was used to fill bone void, and calcaneal plates and screws (Depuy, Warsaw, IN, USA) were used to achieve stable fixation (Figure 1H). After the pins and the external fixator were removed (Figure 1I, 1J), the flap was closed in layers over a drain.

Outcome evaluation

Bohler’s angle, Gissane’s angle and calcaneal height were measured on lateral view X-ray of calcaneus before surgery, after reduction with common technique and after reduction with the external fixator, respectively. Calcaneal width was measured on axial view X-ray of calcaneus at the same time points. Patients were followed up monthly to union of the fractures and annually thereafter. At every follow-up visit, the clinical outcome was evaluated by the Maryland Foot Score [10].

Statistical analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 19.0. Kolmogorov-Smirnov test was performed to evaluate the distribution of continuous data. Mean ± standard deviation, median and range, and number of patients or percentage were employed to describe variables as appropriate. One-way analysis of variance (ANOVA) and SNK post-hoc test were performed to analyze the differences of normally distributed continuous data between time points. A P value less than 0.05 was considered statistically significant.

Results

There were sixteen men and six women with a mean age of 37 years (range, 30 to 44 years). Thirteen patients fractured their left calcaneus and eight fractured their right calcaneus. A bilateral fracture was seen in one patient. Fourteen patients sustained a fall from height, seven were victims in motor vehicle collision and one sustained other injury. According to Sanders classification [10], thirteen fractures were classified as Sanders type III and ten as type IV. The mean injury-to-surgery interval was 11.5 days (range, 2-17 days). The mean follow-up period was 13 months (range, 6 months to 2 years). Wound edge necrosis was noted in one patient (4.35%), which healed at 20 days after
surgery and required no further intervention. No other complications were noted.

The radiological results are shown in Table 1 and Figure 2. The mean preoperative Bohler’s angle, Gissane’s angle, calcaneal height and calcaneal width were 7.33 ± 6.52°, 106.05 ± 10.19°, 53.44 ± 5.16 mm, and 50.71 ± 5.20 mm, respectively. Bohler’s angle was improved to 14.93 ± 7.26° after reduction with common technique.

Figure 2. The radiological outcomes were evaluated by the measurement of Bohler’s angle (A), Gissane’s angle (B), calcaneal height (C), and calcaneal width (D). Common technique, after reduction with common technique; external fixator, after reduction with the external fixator. The bars represent the mean and the standard deviation; The asterisks indicate significant differences between time points on ANOVA and with use of the SNK post-hoc test for multiple comparisons: *P < 0.05 compared with before surgery; **P < 0.05 compared with reduction with common technique.
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Figure 3. The clinical outcomes were evaluated by the Maryland Foot Score at the final follow-up visit. The bars represent the number of patients; excellent, 90-100; good, 75-89; fair, 50-74; poor, < 50.

of all 23 fractures (82.61%) were considered excellent or good.

Discussion

In this study, the outcomes of the application of intraoperative percutaneous traction using an external fixator for the reduction of medial wall shortening and misalignment in calcaneal fractures were evaluated. The results showed that the application of intraoperative percutaneous traction improved Bohler’s angle, Gissane’s angle, and calcaneal width compared with reduction with common technique. Also, the incidence of associated soft tissue-related complications was low (4.35%), and excellent or good clinical outcomes were observed in 84.62% Sanders type III fractures and 80% Sanders type IV fractures.

While the restoration of the mechanical hind-foot axis may play an equally important role to the reduction of the posterior articular facet in the treatment of calcaneal fractures [8], it is unfeasible to restore that through the extended lateral approach [19]. As a result, residual hind-foot varus may exist after ORIF through the extended lateral approach, in particular, in complex displaced intra-articular fractures. Residual hind-foot varus shifts weight bearing to the lateral border of the foot, and facilitates distal talar subluxation, lateralization of the heel fat pad, overload of the tibialis posterior tendon, and diminution of push-off efficiency during gait, and finally, results in severe pain [8, 20]. Hence, the three-dimensional anatomic reconstruction of calcaneus, rather than the reduction of the posterior facet alone, should be requested in the treatment of calcaneal fractures. To achieve this goal, combined lateral and medial approaches, which could achieve accurate reduction of the medial wall and the lateral wall, as well as subtalar joint or calcaneocuboidal joint, were advocated by several authors [21-24]. However, the associated tibial...
nerve, artery, and tendon are intimately contacted with the medial wall, making the internal fixation through the medial approaches less applicable [20]. Moreover, the combined use of lateral and medial approaches will disturb the vascularization further and result in a higher incidence of complications [16].

The poor reduction of the medial wall may be mainly due to the infeasibility to place an adequate longitudinal traction on the half pins or Steinmann pins manually in the treatment of calcaneal fractures with ORIF through the lateral approach. When the longitudinal traction is inadequate, it will be hard to dislodge and reduce the medial wall fragments through the lateral approach. Traction with the external fixator has been used widely in the field of orthopaedic surgery for the advantages of reliable traction and minimal invasion [25]. Therefore, we used intraoperative percutaneous traction with an external fixator to provide the adequate longitudinal traction. The results of our study demonstrated that Bohler’s angle, Gissane’s angle, calcaneal height, and calcaneal width were all improved after reduction with common technique, however, complete anatomic reduction or approximately anatomic reduction was not achieved due to residual hind-foot varus presence. After reduction with the external fixator, Bohler’s angle was improved from 14.93 ± 7.26° to 26.17 ± 4.66° (P < 0.05), Gissane’s angle was improved from 113.37 ± 10.26° to 127.96 ± 6.07° (P < 0.05), and calcaneal width was improve from 41.70 ± 4.63 mm to 37.99 ± 3.30 mm (P < 0.05). Additionally, the introduction of minimally invasive procedure allowed us to minimize the incidence of soft tissue-related complications to 4.35%, which was lower compared with the combined lateral and medial approaches [16]. Moreover, the excellent or good clinical outcomes were observed in 82.61% of Sanders type III or IV fractures (n=19). The more favorable result compared with historical studies indicates that restoration of medial wall shortening and misalignment may play an important role in the clinical outcomes of surgical treatment of calcaneal fractures.

However, it is well accepted that most calcaneal fractures, which are less complex, could be well reduced with common technique, such as percutaneous leverage, manual compression and longitudinal traction. Hence, there is no need to apply our technique to all calcaneal fractures cases. The method of the current study is deemed essential only when medial wall shortening or misalignment could not be reduced with common technique.

In conclusion, intraoperative percutaneous traction using an external fixator represents a safe method that is effective for the reduction of medial wall shortening and misalignment that cannot be well reduced through the lateral approach. The combined use of intraoperative percutaneous traction and open reduction and internal fixation through the extended lateral approach for complex displaced intra-articular calcaneal fractures ensures desirable clinical outcomes.

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Disclosure of conflict of interest

None.

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References


