Original Article
Treatment of open calcaneal fractures using a new external fixator

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Abstract: Background: To explore the clinical efficacy of self-developed calcaneal external fixator for the treatment of open calcaneal fractures. Methods: Retrospective analysis of 18 cases of open calcaneal fractures patients who were recruited from May 2007 to May 2012, including 13 males and 5 females. All patients underwent emergency operation within 8 hours after injury. After general debridement, the calcaneal external fixator was used to perform open reduction and fixation of calcaneal fractures. Then the articular surface of calcaneus was exposed and fixed with Kirschner wire. The length and width of calcaneus, the height of thalamus, the maximum vertical displacement of the posterior articular surface, and Bohler angle were measured before operation, 3 days after operation, and 6 months after operation. Results: All patients were followed for 4-36 months (mean, 25 months). The ipsilateral calcaneus lateral and axial X-ray film 3 days and 6 months after operation showed that anatomical structure of the calcaneus almost restored to the normal, and showed significant difference compared to before operation. There was no significant difference between 3 days and 6 months after operation. CT scan at the last follow-up showed anatomical restoration of posterior articular surface in 18 cases, only 2 cases had < 2 mm displacement of the articular surface. Conclusion: Our calcaneal external fixator can be used easily and effectively to treat open calcaneal fractures.

Keywords: Calcaneus, external fixator, open fractures

Introduction

With economic development, patients with traffic injury and fall injury have increased recently, including patients with open calcaneal fractures. Open calcaneal fractures account for about 3-6% of calcaneal fractures [1-4]. For closed calcaneal fractures, open reduction and internal fixation is considered an effective treatment. However, it is still difficult to treat open calcaneal fracture due to the anatomical features of the calcaneus and weak soft tissue coverage on the surface of the calcaneus. The specific treatment strategy and fixation method for open calcaneal fracture remain to be disputed.

Currently, external fixators have been mainly used for the treatment of open calcaneal fractures, including ring-type external fixators, Ilizarov external fixators, and “U” type external fixators [5]. These external fixators have the disadvantages such as complicated operation and the lack of flexibility. To improve the efficacy and simplify the operation for the treatment of open calcaneal fractures, we developed a special external fixator. From May 2007 to May 2012, we treated 18 cases of patients with open calcaneal fractures using our self-developed external fixator.

Materials and methods

Patients

From May 2007 to May 2012, 18 patients with open calcaneal fractures were recruited, including 13 males and 5 females. As shown in Table 1, these patients aged 21-57 years (mean 36 years). 8 cases were type I and 10 cases were type II according to Gustilo classification of open fractures. 4 cases were type II.
External fixator for open calcaneal fractures

Table 1. Clinical data of the patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Gender</th>
<th>Age (year)</th>
<th>Clinical feature</th>
<th>Surgery outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>44</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>21</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>36</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>49</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>38</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>28</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>39</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>31</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>9</td>
<td>Male</td>
<td>41</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>57</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>11</td>
<td>Female</td>
<td>29</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>40</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>13</td>
<td>Male</td>
<td>36</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>14</td>
<td>Male</td>
<td>50</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>15</td>
<td>Female</td>
<td>41</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>16</td>
<td>Male</td>
<td>36</td>
<td>Type I open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>17</td>
<td>Male</td>
<td>32</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
<tr>
<td>18</td>
<td>Female</td>
<td>27</td>
<td>Type II open fracture</td>
<td>Good</td>
</tr>
</tbody>
</table>

Figure 1. The self-developed calcaneal external fixator. A: General appearance. B: Postoperative appearance.

Preoperative preparation

After admission the patients were intramuscularly injected with tetanus antitoxin or human anti-tetanus immune globulin, and received intravenous injection of antibiotics to prevent infection. All patients were examined in detail for possible fracture of the spine, hip and other parts. Calcaneal lateral and axial X-ray images and calcaneal 3-dimensional CT scan were performed. All patients underwent phase I surgery within 12 hours of admission.

Operation

After preoperative preparation, surgery was performed with spinal anesthesia and the patients were kept at supine position. First, debridement was carried out to remove contaminants, necrotic tissue and blood clots. After the wound was cleaned, the calcaneal external fixator was selected according to the size of the affected foot and installed (Figure 1).

Postoperative management

All patients were given intravenous infusion of the second generation cephalosporins for 3 days. The patients were encouraged to do flexion and extension exercises with lower limbs and other joints, plantar flexion and dorsiflexion of toes. Three days after surgery, lateral and axial X-ray images of affected foot was taken, and CT scan was used to check the reduction of fractures. Two months after surgery, the external fixator and Kirschner wire were removed. Three months later, the patients gradually began weight-bearing walking.

Efficacy evaluation criteria

According to the criteria of Buekley et al. [7], the reduction of posterior articular surface was evaluated by CT scan and divided into three

cases were type III and 3 cases were type IV according to Sanders classification [6].

External fixator

Self-developed calcaneal external fixator (patent No. ZL200920083929.X) was composed of the “U”-shaped universal joints on both sides and the telescopic threaded rod and the corresponding sleeve in the middle (Figure 1). The external fixator could be installed close to the body surface, and the diameter of the needle was small to reduce tissue damage. The length of the middle threaded rod ranged from 4 cm, 5 cm, to 6 cm, and reached 4-7 cm, 5-9 cm, 6-11 cm, respectively, after stretching to meet the needs of different patients.
External fixator for open calcaneal fractures

Table 2. Comparison of measurements before operation, 3 days after operation, and 6 months after operation (n=18)

<table>
<thead>
<tr>
<th>Item</th>
<th>Preoperative</th>
<th>3 days after operation</th>
<th>6 months after operation</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of calcaneus (mm)</td>
<td>81.00±6.89</td>
<td>87.13±6.80</td>
<td>87.07±6.61</td>
<td>61.95</td>
<td>0.000</td>
</tr>
<tr>
<td>Width of calcaneus (mm)</td>
<td>56.03±8.90</td>
<td>45.20±6.40</td>
<td>45.27±6.31</td>
<td>104.22</td>
<td>0.000</td>
</tr>
<tr>
<td>Height of thalamus (mm)</td>
<td>33.43±4.96</td>
<td>43.33±5.49</td>
<td>43.23±5.45</td>
<td>152.07</td>
<td>0.000</td>
</tr>
<tr>
<td>Maximum vertical displacement of posterior Articular surface (mm)</td>
<td>10.10±4.34</td>
<td>0.17±0.53</td>
<td>0.17±0.53</td>
<td>162.01</td>
<td>0.000</td>
</tr>
<tr>
<td>Bohler angle (°)</td>
<td>1.00±15.99</td>
<td>31.27±4.37</td>
<td>30.87±4.52</td>
<td>108.73</td>
<td>0.000</td>
</tr>
</tbody>
</table>

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Figure 2. Typical X-ray images of a patient (female, 41 years old). A. Preoperative lateral and axial X-ray of left calcaneus showing the displacement of fracture. B. Lateral and axial X-ray of left calcaneus at postoperative 3 day. C. Lateral and axial X-ray of left calcaneus at postoperative 6 months.

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of the articular surface; irregular articular surface and > 2 mm displacement of the articular surface.

Statistical analysis

Statistical analysis was performed using SPSS 17.0 software. The length and width of calcaneus, the height of thalamus, the maximum vertical shift of posterior articular surface and Bohler angle measured preoperatively, postoperatively at 3 days and postoperatively at 6 months were compared by ANOVA. If the difference between the groups was statistically significant, Bonferroni method was used for pairwise comparison. P < 0.05 indicated that the difference was statistically significant.

Results

All patients were followed for 4-36 months (average 25 months). 6 patients with surface infection were cured after therapy, no patients had skin necrosis, deep infection, non-union, osteomyelitis and other complications or amputation.

Statistical analysis showed that the length and width of calcaneus, the height of thalamus, the maximum vertical displacement of posterior articular surface and Bohler angle at postoperative 3 days and post-
operative 6 months were significantly different from preoperative values (all P=0.000, Table 2), while there were no significant differences between postoperative 6 months and postoperative 3 days. Radiographic examination showed that the anatomical structure of calcaneus was restored to the normal range, and the height of fracture reduction was normal (Figure 2).

CT scan at the last follow-up showed that 16 cases (16/18, 89%) had anatomical reduction of the posterior articular surface, and 2 cases (2/18, 11%) had irregular articular surface and <2 mm displacement of the articular surface. There was no case of traumatic arthritis, fibular tendonitis, claw foot deformity, dorsiflexion and plantar flexion of affected foot in the patients during follow-up.

Discussion

Open calcaneal fractures are mostly caused by fall injury, and a small number of them are caused by traffic accidents. The calcaneus is located on the lateral side of the talus. When falling from high place, the heel is subjected to axial load. The talus is fractured by the shearing of the talus. During calcaneal fracture, the width of the calcaneus increases and the inner and outer soft tissues undergo shear tension [8-10].

For open calcaneal fracture, the presence of severe skin and soft tissue damage, including skin tearing, de-sleeving, rolling, and even soft tissue defects and wound contamination makes the treatment complex, and the patients are more prone to skin necrosis, wound infection, calcaneal delayed healing or even non-union. Emergency surgical debridement is recognized as the standard treatment for open calcaneal fracture, but there is a wide range of controversy on the use of reduction and fixation treatment. The timing and method of fracture fixation are the key issues to determine the prognosis of open calcaneal fractures.

Franklin et al. performed emergency surgery for 38 cases of open calcaneal fractures and found that early surgery with internal fixation and delayed closure of the wound had advantages such as short hospital stay and satisfactory function recovery [11]. Heier et al. reported 9-year follow-up of 19 cases of open calcaneal fractures. They concluded that open calcaneal fractures have a high propensity for deep infection. While type-I and type-II open fractures associated with a medial wound can be treated with open reduction and internal fixation, type-III open fractures require extensive debridement and prompt soft-tissue coverage, and early internal fixation should be avoided [12]. Aldridge et al. reported follow-up of 19 cases of open calcaneal fractures for 10 years, and suggested that internal fixation should not be done during emergency debridement, and reduction and internal fixation should be postponed [9]. Benirschke and Kramer reported that the infection rate of open calcaneal fractures was 7.7%, while the infection rate of closed calcaneal fractures was 1.8%. They concluded that the extension of the lateral approach was safe and effective [13].

In this study we designed a new type of universal joint at both ends of external fixator so that it can be close to the skin and locked, and enhance the biomechanical stability of the external fixator. It does not affect wound treatment of open calcaneal fractures, after thorough debridement, the wound surface was used for overall reduction. The bar of external fixator between the calcaneal tubercle and the navicular-cuboid bone was extended, and the length, width, axis of the calcaneus restored to normal range. These results are consistent with previous opinion that open reduction and internal fixation of intra-articular calcaneal fractures only benefit those patients in whom anatomical reconstruction is achieved [14].

While the wound was treated in phase I, the reduction of articular surface was done through the medial wound or assisted by external small incision. Kirschner wire was fixed to further enhance the stability of the fracture block of articular surface and reduce the risk of postoperative infection. The results showed that there was no significant difference in the anatomy of calcaneus between 3 days after operation and 6 months after operation, indicating that calcaneal external fixator could achieve firm fixation. In addition, we found that Kirschner wire drilling into navicular-cuboid bone should be performed under X-ray fluoroscopy to avoid the injury to small joints of the feet.

In summary, we used self-developed calcaneal external fixator to treat calcaneal fractures, the
debridement can be performed together with the reduction of fractures, reducing the occurrence of infection after the use of internal fixation and shortening the time of hospitalization. Therefore, our calcaneal external fixator can be used easily and effectively to treat open calcaneal fractures. However, further large-scale studies are needed to validate the advantages of self-developed calcaneal external fixator.

Disclosure of conflict of interest
None.

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References


