Calcaneus bone intra-articular fracture treatment by the closed reduction and percutaneous fixation with cannulated screw method in high-risk patients: A pilot trial

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OBJECTIVE: Debate surrounding the methods for optimal treatment of calcaneal fractures is controversial. One method, closed reduction and percutaneous fixation, can restore the height, width, length and shape of the hindfoot by restoring the orientation of the calcaneal posterior facet. The aim of this study was to evaluate the treatment of intra-articular fractures of the Calcaneus bone with this method, especially in patients unsuitable for open reduction surgery.

METHOD: 49 patients with intra-articular fractures underwent closed reduction and percutaneous fixation surgery between 2014 and 2016 in Taleghani Hospital. After 12 months of follow up, pain, functional outcome, range of motion, and change in footwear were evaluated with the use of the criteria from the American Orthopedic Foot and Ankle Society (AOFAS).

RESULT: Out of 49 patients, 42 were male and 7 were female. All cases demonstrated bony union, with an average Bohler’s angle of 25.92 ± 7.93 and Gissane’s angle of 115.39 ± 11.24. At the 12 months’ follow-up, the mean values of the AOFAS score were 73.3 ± 7.08. The changes in Bohler’s angle, VAS and AOFAS score did not differ significantly between patients with blister and without blister, and also between the smokers and non-smokers subgroups. Neither deep infection nor osteomyelitis was seen.

CONCLUSION: Closed reduction and percutaneous fixation of calcaneus fractures using cannulated screws can be a safe and effective method for treating calcaneus fractures.

Key Words: Intra-articular calcaneus fractures; Percutaneous screw fixation; Sanders classification; Closed reduction

The optimal treatment of intra-articular fractures of the calcaneus is under debate. Open reduction and internal fixation (ORIF), using a combination of plates and screws, is considered a standard treatment for displaced intra-articular fractures, providing satisfactory outcomes in the majority of patients. However, ORIF is contraindicated in smokers and patients with poor soft tissue condition or vascular insufficiency (6-8). Various subsequent complications have also been frequently reported (9).

The percutaneous approach has been recommended as combining the benefits of operative intervention with a reduced risk of infection through small incisions (10). Following the above concerns, it was decided to evaluate the outcomes of closed reduction and percutaneous fixation of intra-articular calcaneus fractures using cannulated screws in this study.

MATERIAL AND METHODS

Patients and settings

In this caseries study, 49 patients with intra-articular Cfs underwent closed reduction and percutaneous fixation with cannulated screws. Cases were selected via convenience sampling among patients referred to Taleghani hospital, affiliated to Shahid Beheshti University of Medical Sciences (SBMU), Tehran, Iran, from July 2014 to May 2016. The exclusion criteria were defined as aged under 12, fractures in other locations, extra-articular fractures, and type 1 fractures based on Sanders’ classification. The study protocol was approved by the Ethics Committee of SBMU.

Demographic and clinical parameters were recorded. Plain radiography, including the ankle series (anteroposterior, lateral view), as well as an axial (Harris) view, was obtained. Bohler’s and Gissane’s angle were measured on X-rays. Furthermore, a spiral CT scan of the hindfoot was performed to determine Sanders’ classification.

Surgical technique

Patients were stabilized on a radiolucent operating table in the lateral decubitus position (Figure 1). C-arm was properly placed in the imaging setup for obtaining X-rays in the sagittal and axial directions. Surgery was conducted by a single attending orthopedic surgeon in the following 4 steps:

Disimpaction

A pin of size 4.5 mm was inserted from the lateral side into the calcaneal tuberosity. With manual longitudinal traction through the forefoot to calcaneus and Varus-Valgus levering, calcaneus length and dis-impaction of the fracture fragments was achieved (Figure 1).

Reduction

In the joint depression type, by inserting a 2.5 or 3 mm pin percutaneously,
the fragments of the posterior facet were levered into its anatomical position. The joint surface reduction was monitored under the guidance of C-arm fluoroscopy. At the same time, all attempts were made to restore acceptable Bohler’s and Gissane’s angles (Figure 2).

Subsequently, the whole construction was fixed with one or two 3.5 or 4 mm cannulated screws introduced to the undersurface of the posterior facet to prevent articular surface collapses (Figure 3). In some cases, this process could be achieved by inserting one or two 3.5 or 4 mm cannulated screws through the postero-inferior aspect of the calcaneus distal to insert the Achilles tendon to the undersurface of the posterior facet in the oblique direction.

Re-impaction
This step involved lateral compression of the bone in order to reduce calcaneal width and prevent lateral impingement. After assuring a favorable reduction, a suitable number of 3.5 mm screws were transversally placed from the lateral side (trampoline screw) along the posterior articular facet into the sustentacular fragment, which is termed the Constant fragment, using the Borden view. A proposed method to reduce the radiation time involves locating the Trampoline screw properly by putting 2 pins in the anterior and the posterior border of the fibula, and using the central of these 2 pins to determine the correct entrance location (Figure 4, 5A and 5B).

Length restoration
In the last step, the calcaneal tuberosity was fixed to the anterior part of the calcaneus with one or two 6.5 mm cannulated screws percutaneously to maintain bone length (Figure 6).

Post-op care and follow-up
A short leg posterior splint was applied. Patients were advised to only engage in non-weight-bearing activities for the first 6 weeks, and to perform isometric exercises of the cuff muscles. After 6 weeks, the posterior splint was removed during the day but applied at night. Patients carried out toe-touch weight bearing with passive and active exercises of the ankle and toes during the day. Full weight bearing started after 12 weeks. After one year, Bohler’s and Gissane’s angle were measured again. In the final visit, the reduction and union status, along with the occurrence of complications (such as screw head irritation and infection) were recorded. Patients were also requested to report their severity of pain using the Visual Analog Scale (VAS). To determine the outcome of treatment, the American Orthopedic Foot and Ankle Score (AOFAS) questionnaire was completed for all patients as part of the final visit. In addition, the extent of previous functional level recovery was assessed using the Tegner activity scale. The patient’s ability to return to work was also examined.

STATISTICAL ANALYSIS
Continuous variables were statistically summarized in terms of mean ± SD, or as a median with interquartile and total ranges. Categorical data are presented numerically (percentage). The Shapiro-Wilk’s W-test was used to assess the normality assumption of continuous variables. One way repeated measure ANOVA was conducted to examine the differences of continuous variables at three time points. Paired t-tests or Wilcoxon signed rank tests, wherever appropriate, were used to compare the continuous variables between two time points. Generalized Estimating Equation (GEE) models were applied to examine the associations between Sanders classification types and changes in the study outcomes of. GEE models included two main effects, and the interaction of these effects. The same models were used to examine the associations between both smoking status and blister status and study outcomes over the course of the study.

RESULTS
49 patients with Cfs were treated, 42 males (85.71%) and 7 females (14.28%). The mean ± SD age of patients was 38.04 ± 13.75, with a range of 12 to 67 years. The other demographic data are shown in Table 1.

TABLE 1
Demographic and clinical parameters

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male</th>
<th>42 (85.71%)</th>
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<tr>
<td>Female</td>
<td>7 (14.28%)</td>
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<tr>
<td>Age</td>
<td>38.04 ± 13.75</td>
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<tr>
<td>Smoker n (%)</td>
<td>22 (44.90%)</td>
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<tr>
<td>Opium addict n (%)</td>
<td>4 (8.16%)</td>
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<td>Diabetes mellitus</td>
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<tr>
<th>Cause of Fx</th>
<th>Falling down</th>
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<tr>
<td>Traffic accidents</td>
<td>8 (16.33%)</td>
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<tr>
<th>Type of Cf</th>
<th>Tongue type</th>
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<tr>
<td>Joint depression</td>
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<tr>
<th>Sanders ‘Classification</th>
<th>Type II</th>
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<tr>
<td></td>
<td>Type III</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Type IV</td>
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The median interval between the occurrence of fracture and surgery was four days. Only 4 patients had superficial infections. Post-operative swelling of the surgery site was observed in 23 cases (46.94%). At the final visit, 33 patients (67.35%) complained of pain caused by the screw head. 26 patients (53.06%) returned to their job within 12 months after the surgery (Post-op). The median VAS was 4 and the median, Tegner activity level scale changed from 3 to 2, showing a significant reduction between pre-operation and the final visit (P<0.001).

The mean AOFAS was 73.31 ± 7.08, 12 months after surgery (range: 61 to 95). The mean ± SD Bohler’s angle significantly increased over the study period from 20.20 ± 10.43 (range: 0° to 42°) to 28.26 ± 7.01 (range: 5° to 40°) (P<0.0001). At the final visit, the mean Bohler’s angle value was 25.92 ± 7.93 (range: 10° to 41°), showing a significant difference between post-op and the final visit (P=0.004). The mean Gissane’s angle was significantly different at the three time points (P<0.0001). The mean ± SD Gissane’s angle Pre-op was 129.10 ± 16.17, which was significantly reduced to 114.04 ± 9.42 (P<0.0001), and it was 115.39 ± 11.24 at the final visit. There was no significant difference of these values Post-op in comparison with the final visit.

There were no significant differences seen among Sanders classification types in VAS, AOFAS, Post-op inflammation status, and return to employment within 12 months after surgery (Table 2). The pattern of changes in Gissane’s angle values did not differ significantly over time among the Sanders classification types (Table 2). The mean percentage reduction of Gissane’s angle values from Pre-op to Post-op was 9.06%, 13.02% and 12.69% in Sanders classification types II, III and IV, respectively (Table 2). A significant reduction was observed from Pre-op to Post-op in type III (P<0.001).

The changes of Bohler’s angle scores differed over the study period among the three Sanders classification types. A significant reduction was observed in the Tegner activity level scale values were similar over time among the three Sanders classification types. A significant reduction was observed from Pre-op to Post-op in type III (P<0.001).

The mean percentage reduction of Gissane’s angle values from pre-surgery to post-surgery (Table 2). The changes of Tegner activity level scale values were similar over time between patients with and without blisters (Table 2). A significant reduction was observed in the Tegner activity level scale values from the final visit compared to Pre-op in both patients with and without blisters (P<0.003 and P<0.001, respectively).

**DISCUSSION**

The best method for the treatment of Cfs still remains controversial (11,12). The use of minimally invasive methods has been described by Westhues et al. (13). The use of minimally invasive techniques and screw fixation techniques has been evaluated in several studies (14-17).

Although the goal of Cfs treatment is the reconstruction of the posterior facet and the normal shape of the heel, it seems that it is not necessary to have an anatomical reduction in the posterior facet in order to obtain satisfactory clinical results; rather the reconstruction of the normal form of the hindfoot is much more important (18). The relationship of Bohler’s angle with the results of intra-articular fractures of the calcaneus has been proven in previous studies (19). The Bohler’s angle significantly increased after surgery and remained in a normal range one year after surgery. Also, Gissane’s angle decreased Post-op and interestingly, with regard to the downward and upward changes, its angle remained within the range of normal values at the 12-month stage (20). According to these results, closed reduction and percutaneous fixation with cannulated screw is able to

<table>
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<th>Sanders classification</th>
<th>Smoking status</th>
<th>Blister</th>
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<td>Tegner activity level scale</td>
<td>Type II</td>
<td>Type III</td>
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<tr>
<td>VAS</td>
<td>3; (2 to 4.5); (1 to 6)</td>
<td>4; (3 to 5); (2 to 6)</td>
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<td>AOFAS</td>
<td>72.94 ± 8.08</td>
<td>73.74 ± 6.81</td>
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<td>Prior to surgery</td>
<td>3; (2 to 3.5); (2 to 4)</td>
<td>3; (2 to 4); (2 to 4)</td>
</tr>
<tr>
<td>Final visit</td>
<td>2; (1 to 3); (1 to 4)</td>
<td>3; (2 to 3); (1 to 4)</td>
</tr>
</tbody>
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**Bohler’s angle**

| Prior to surgery | 18.24 ± 2.53 | 22.11 ± 2.00 | 16.60 ± 4.66 | 20.77 ± 9.34 | 19.56 ± 11.72 | 20.77 ± 11.40 | 19.74 ± 9.76 |
| After surgery | 28.85 ± 5.88 | 27.85 ± 5.88 | 31.20 ± 5.76 | 28.42 ± 8.27 | 28.09 ± 5.44 | 27.82 ± 7.93 | 28.63 ± 6.30 |
| Final visit | 26.53 ± 8.60 | 24.44 ± 7.29 | 31.80 ± 7.33 | 26.69 ± 9.50 | 25.04 ± 5.76 | 25.91 ± 8.02 | 25.92 ± 8.00 |

**Gissane’s angle**

| Prior to surgery | 124.06 ± 15.62 | 131.67 ± 16.42 | 132.40 ± 15.58 | 131.35 ± 16.92 | 126.58 ± 15.25 | 129.27 ± 15.15 | 128.96 ± 17.24 |
| After surgery | 112.82 ± 9.09 | 114.52 ± 10.26 | 115.60 ± 6.23 | 112.15 ± 8.96 | 116.17 ± 9.87 | 114.45 ± 10.25 | 113.70 ± 8.87 |
| Final visit | 114.00 ± 9.86 | 117.00 ± 12.07 | 111.40 ± 11.61 | 113.73 ± 11.48 | 117.26 ± 10.91 | 117.54 ± 10.88 | 113.63 ± 11.42 |
| Post-surgery inflammation, N (%) | 7 (41.18%) | 13 (48.15%) | 3 (60.00%) | 13 (50.00%) | 10 (43.48%) | 10 (45.45%) | 13 (48.15%) |
| Return to job, N (%) | 10 (58.82%) | 14 (51.85%) | 2 (40.00%) | 12 (46.15%) | 14 (60.87%) | 12 (54.54%) | 14 (51.85%) |
restore acceptable hindfoot shape and height, with the final Bohler’s and Gissane’s angles in normal ranges.

These results can be compared with the findings of studies which used similar less invasive fixation methods (18) and internal fixation with a wide lateral approach (21). There are significant differences between studies in non-surgical values (22). Non-surgical treatment methods have been associated with poor clinical therapeutic outcomes (11). Levine et al. observed that subtalar joint movement is maintained with an anatomical reduction using percutaneous fixation (17). Abdelgaid et al. fixed calcaneus fractures using 4 mm and 6 mm cannulated screws and observed no cases of wound infection or other complications during a 29 month follow-up period, with only three cases of reduction loss due to early weight gain reported (16). Also, Dewall et al. used 3.5 mm or 4 mm cannulated screws and their results were compared to the ORIF method. The results presented a significant difference between the two methods in terms of the incidence of wound complications and deep infection (10). ORIF is supported by many reports, as one type of treatment for most intra-articular calcaneus fractures, but rate of complication remains noteworthy (23,24).

In this study, high-risk patients with intra-articular Csfs can be safely managed using percutaneous reduction and fixation. The changes of Bohler’s and Gissane’s angle, VAS and AQoFAS did not differ significantly between patients with and without blister, and the differences between smokers and non-smokers is consistent with Hammond’s study (15). Smoking and blisters did not affect return to employment within the 12 months after surgery. Csfs is associated with bad skin conditions like blisters, which is challenging for many orthopaedics surgeons. Most studies indicate the impact of fracture blisters, especially on delays in surgical management and higher risks of complications (25).

In this study, the presence of blisters did not affect delays in surgery. No Postop complications were observed in this group. The most common complication of this technique was skin irritation. It occurred due to inappropriate countersinking of the screw heads. This issue led to superficial infections in some cases. This study was limited by its small sample size. Long term follow-up could be helpful in evaluating the amount of subtalar arthrosis, compared with other techniques.

CONCLUSION
Closed reduction and percutaneous fixation using cannulated screws can be used in cases involving undesirable soft tissue conditions with a low risk of infection. Skin problems and being smokers are relative contraindications of open surgery.

Since this method is able to restore the heel shape and the posterior facet reduction as much as other less invasive techniques, it can be applied as an alternative technique suitable for patients with unfavorable conditions in open surgical procedures and internal fixation.

REFERENCES