Percutaneous Reduction and Screw Fixation of Displaced Intra-articular Fractures of the Calcaneus

Saran Tantavisut, MD1, Phinit Phisitkul, MD2, Brian O. Westerlind, BS2, Yubo Gao, PhD2, Matthew D. Karam, MD2, and John L. Marsh, MD2

Abstract
Background: Extensile open approaches to reduce and fix intra-articular calcaneal fractures are associated with high levels of wound complications. To avoid these complications, a technique of percutaneous reduction and fixation with screws alone was developed. This study assessed the clinical outcomes, radiographs, and postoperative CT scans after operative treatment with this technique.

Methods: 153 consecutive patients with 182 intra-articular calcaneal fractures were reviewed. All patients were assessed for early postoperative complications at 3 months from the injury. The clinical results were assessed for patients seen at a minimum of 1 year after surgery (mean follow-up of 2.6 years; 90 patients, 106 feet). In patients who had both preoperative and postoperative CT scans (50 patients, 60 feet), the articular reduction was quantitatively analyzed.

Results: At the 3-month follow-up, there were 1% superficial infections and 1% rate of screw irritation. The complications at a minimum of 1 year after injury included screw irritation 9.3%, subtalar osteoarthritis requiring subtalar fusion 5.5%, malunion 1.8%, and deep infection 0.9%. Bohler angle, calcaneal facet height, and width were significantly improved postoperatively ($P < .01$). Bohler angle increased on average +24.1 degrees postoperatively with a loss of angle of 4.9 degrees at the 3-month follow-up. There was significant improvement ($P < .01$) in posterior talocalcaneal joint reduction on postoperative CT scan but residual displacement remained. At the final follow-up, 54.5% of the patients reported a residual pain level of 3 or lower.

Conclusion: This study suggests that reasonable early results could be achieved from the percutaneous treatment of intra-articular calcaneal fractures using screws alone based on articular reduction and level of residual pain.

Level of Evidence: Level IV, retrospective case series.

Keywords: intra-articular calcaneal fracture, percutaneous reduction, percutaneous fixation, screw fixation

Introduction
The optimal treatment of displaced intra-articular fractures of the calcaneus remains controversial.19,24 Historically, nonoperative treatment was commonly used due to the unpredictable results and high complication rates of operative treatment. In the past 2 decades, operative treatment, most commonly using an extensile lateral open approach to reduce and fix fractures using plates and screws, has become the preferred approach. Unfortunately, this approach is associated with high rates of wound complications.14,11 Yu et al performed a systematic review of 21 articles (2046 open approach cases) and found the rate of infection and skin flap necrosis to be 13.6%.34

To minimize complications, percutaneous approaches to reduce and fix calcaneal fractures have reported satisfactory results. In most case series, these techniques were used only for selected calcaneal fractures such as tongue type patterns because of concern that limited approaches lead to less accurate articular reductions.20,21,32 The senior authors developed a technique of percutaneous reduction and fixation with screws alone for all intra-articular calcaneal fractures without any exclusions and have used this technique since 1999.13 This study aimed to provide follow-up information for a large group of patients, with clinical outcomes and standard radiographic assessment. It directly assessed the articular reduction issue by using a novel comprehensive articular...
measurement technique based on postoperative computed tomographic (CT) scans. We hypothesized that the percutaneous technique for reduction and fixation with screws alone could yield comparable results to a standard open approach as reported in the literature with less complications. The study examined important factors relevant to the use of percutaneous techniques and fixation with screws alone: (1) early postoperative complications with an average 3-month follow-up; (2) clinical outcomes, early complications, and secondary procedures in patients with a minimum of 1 year follow-up; (3) the degree to which reductions were obtained and maintained as determined by initial and 3-month radiographs; (4) quality of postoperative articular fracture reduction and fixation using a novel triplanar articular measurement from postoperative CT scans.

Methods

From 2000 to 2011, a consecutive series of 153 patients with 182 displaced intra-articular fractures of the calcaneus were identified that were treated operatively with a technique of percutaneous reduction and fixation with screws alone.13 During this time period, patients were not treated with extensile or other open approaches and there were no patients treated with primary subtalar fusion.

The demographic data are listed in Table 1 and describes the 153 patients (121 male, 32 female) with 182 intra-articular calcaneal fractures. The patients’ average age was 41.9±13.9 years. Fractures were classified based on Sanders classification, with comminuted fractures (grade 3 and 4) accounting for 50%. The majority of fractures were closed (94.5%). The average follow-up for all patients was 1.8 years (standard deviation of 1.7 years, range 90 days to 8.9 years). All patients were seen at a minimum of 3 months from injury.

Operative Technique

The details of the operative technique have been previously described.13 The patients were placed in lateral decubitus position on a radiolucent operating table, with a firm bump underneath the injured foot to support a perfect lateral position. The surgeon stood posterior to the patient with the C-arm entering the operative field opposite them from the end of the bed. The surgeon ensured that satisfactory lateral, Broden, and Harris views were easily attained.

In order to treat joint depression fractures, the tuberosity was reduced first using a corkscrew placed from lateral to medial through the calcaneal tuberosity followed by manipulation of the tuberosity out of an obstructing position to allow facet reduction. Once the tuberosity was reduced, 1.6-mm Kirschner wires placed from the posterolateral aspect of the tuberosity into the medial sustentaculum temporarily fixed the fracture. Facet fragments were then reduced under fluoroscopic assessment with small instruments through multiple stab incisions and fixed temporarily with Kirschner wires placed lateral to medial. After the fractures were satisfactorily reduced on the 3 C-arm views (lateral, axial, and Broden view), the surgeon then definitively fixed the fracture(s) with 3.5- and 4.0-mm cannulated screws.

For tongue-type fractures, two 3.2-mm Steinmann pins were placed parallel to each other into the facet (tongue) fragment(s) posterior to anterior. Reduction of the fracture was achieved by manipulating the Steinmann pins in coordination with small instrument(s) placed through stab incision(s). After a satisfactory reduction was confirmed by fluoroscopic assessment, multiple 3.5- or 4.0-mm screws were placed from posterosuperior to anteroinferior and from lateral to medial into the sustentaculum to stabilize the tongue fragment. The Steinmann pins were then removed, but occasionally in the most severe cases, they were driven into the cuboid to support the reduction and removed after 4 weeks. Postoperatively, the leg was placed into a short leg cast or removable splint, followed by non-weight bearing for 8 to 10 weeks before the patient began progressive weight bearing.

Patient Identification and Outcome Measures

This study was approved by the institutional review board before review of hospital records to identify all patients. All
operative records, trauma service database information, and radiographic data were retrospectively reviewed from the time of injury to the most recent follow-up. In all patients (153 patients / 182 feet) postoperative complications were assessed at a minimum of 3 months from the injury, and their radiographs were measured to assess the degree to which the fracture was reduced and the reduction maintained. Early complications were identified from the records and included superficial infections (defined as infection that involved only skin and subcutaneous tissue of the incision), deep infections (defined as infection that related to the operation and involved deep soft tissue such as fascia, muscle), and the need for screw removal. Other miscellaneous complications were also identified and documented from the medical records. Clinical results, late complications (same as early complications), and secondary procedures were assessed in a subgroup of patients with a minimum of 1 year’s follow-up after surgery. The clinical results were evaluated from patient records including the department’s electronic database, which had a visual analog scale (VAS) pain score filled out by all of the patients at the time of clinic visits. Postoperative activity level, stiffness, and pain score were recorded by a single senior surgeon and reported into the medical record. The activity level was classified as excellent if patient did not have any limitation to work, moderate activity deficit if they had limitation to mild to moderate work, and severe activity deficit if they had limitation to household activity. The ability to return to work was also obtained and recorded at clinic visits by the senior surgeon. The stiffness measurement was performed by comparing affected side motion with normal motion. The heel was grasped with one hand and the leg stabilized with the other. The amount of inversion and eversion was compared to the other side by an estimate made by one of the senior surgeons.

Radiographic Measurement Techniques

Lateral and Harris view plain radiographs of the fractured calcaneus were used to measure Bohler angle, Gissane angle, the talocalcaneal angle, calcaneal width, height, and length. These measurements were made on preoperative, immediate postoperative, and 3-month postoperative radiographs (Figure 1). Late-stage arthritis and fusion was evaluated in the subgroup of patients who had >1 year’s follow-up (90 patients, 108 feet), and all patients who had more than 1 year of follow-up had radiographs at their latest follow-up. A subset of patients had complete preoperative and postoperative CT scans to assess reduction and hardware placement. The postoperative CT was obtained the day following surgery. In these postoperative CT scans (50 patients, 60 feet), articular reduction was quantitatively measured using a CT-based measurement technique (Figure 2). The widest displacements between fractured subchondral surfaces in the anterior-talocalcaneal joint (anterior and middle facets), posterior-talocalcaneal joint, and calcaneocuboid joint were measured in the sagittal, horizontal, and coronal planes. The maximum articular displacement measured on the CT scan was defined as the summation of the greatest displacement measured at each location from the 3 planes. All radiographic evaluation and measurements were performed by a fellowship-trained orthopedic traumatologist who was not involved in the patient care.

Statistical Analysis

Data were analyzed using descriptive analysis and paired t test for dependent variables. Significant differences were defined as having a P value ≤.05. Multiple variables (smoking status, workers compensation status, and open injury)
were correlated with activity, pain, stiffness, ability to return to work, and complications using logistic regression.

Results

Early postoperative complications within 3 months of injury (all patients, 153 patients / 182 feet) were found in 4 patients (2%). There were 2 superficial infections (1%). One patient developed irritation of the posterior tibial nerve, requiring a screw removal (0.5%). Another patient was found to have screw penetration of the subtalar joint requiring screw removal (0.5%).

Patients with a minimum of 1 year’s follow-up (90 patients, 108 feet) had a mean follow-up of 2.6 years (range 1-8.9 years). Sixty-three patients were lost to follow-up between 3 months and 1 year from injury and were not included in this analysis. Complications (Table 2) that required secondary procedures occurred in 21 of 108 feet. There was one deep infection that had developed secondarily over the prominent plantar bone that required a debridement of the prominent bone and antibiotics which resolved. There were 7 subtalar arthrodeses (6.5%) at an average of 3.5 years (standard deviation 1.6 years). Hardware removal was performed in 10 patients (9.3%).

Table 2. Midterm Complications.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Foot/Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midterm complications (108 feet)</td>
<td></td>
</tr>
<tr>
<td>Screw irritation</td>
<td>Remove screws</td>
</tr>
<tr>
<td>Subtalar osteoarthritis</td>
<td>Subtalar arthrodesis</td>
</tr>
<tr>
<td>Prominent bone</td>
<td>Excision fragment</td>
</tr>
<tr>
<td>Deep infection</td>
<td>Debridement</td>
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<tr>
<td>Achilles tendinopathy</td>
<td>Repair Achilles tendon</td>
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</tbody>
</table>

Pain on the VAS was the main patient reported clinical outcome. Thirty-four patients (37.8%) reported a pain VAS score of 0, 15 patients (16.7%) reported scores of 1 to 3, 27 patients (30%) reported scores of 4 to 6, and 14 patients (15.6%) reported scores of 7 of 10. Overall, 54.5% of the entire cohort reported a residual pain level of 3 or lower. The subtalar examination demonstrated normal motion in 22 patients (24.4%), subtalar motion >70% compared to the normal side in 25 patients (27.8%), subtalar motion 30% to 70% compared to the normal side in 27 patients (30%), and subtalar motion less than 30% compared to the normal side in 16 patients (17.8%).

The results of the radiographic measurements on plain radiographs in the whole group of patients (153 patients / 182
feet) are shown in Table 3. There was a significant improvement in Bohler angle ($P < .01$), calcaneal facet height ($P < .01$), and calcaneal width ($P < .01$) on postoperative radiographs. On 3-month postoperative radiographs, all measurement parameters were well maintained except the Bohler angle, which decreased on average 4.9 degrees from 18.0 ± 11.0 degrees postoperatively to 13.1 ± 15.5 degrees at 3 months postoperatively.

The triplanar articular measurements of 50 patients (60 feet) on CT scans are shown in Table 4. There was significant improvement in posterior talocalcaneal joint displacement from 28.3 ± 13.5 mm preoperatively to 12.9 ± 15.7 mm postoperatively ($P < .01$). The calcaneocuboid joint was improved from 2.1 ± 2.6 mm preoperatively to 1.2 ± 1.9 mm postoperatively ($P < .05$).

Logistic regression analysis for factors that may have influenced operative outcome is shown in Table A1 (appendix) using a $P$ value of .05 or less as significant. Smoking had the most significant correlations with the dependent variables, including postoperative activity level, VAS pain score, postoperative stiffness, and the ability to return to work. The ability to return to work was reported by 87.5% of all participants. The preoperative CT articular displacement scores showed significant correlations with postoperative activity level and the rate of late-stage arthritis or subtalar fusion. The postoperative CT articular displacement scores correlated with VAS pain scores and the rate of late-stage arthritis or subtalar fusion. It did not correlate with postoperative activity, postoperative stiffness, ability to return to work, and screw complications. The workers compensation, open injury, and Sander classifications did not correlate with any of the dependent variables. Preoperative Bohler angle were correlated with the rate of late-stage arthritis or subtalar fusion, whereas immediate postoperative and 3-month postoperative Bohler angles were not correlated with any of the dependent variables.

**Discussion**

A wide variety of treatment options have been used for intra-articular calcaneal fractures.\(^{19,24}\) Since the early 1990s, an extended lateral approach for reduction and fixation using plates and screws has grown in popularity.\(^4\) Despite these advancements, wound complications remain a problem (0.4%-14% of the cases), because of a vulnerable soft tissue envelope.\(^1,11,20,25\) Haugsdal et al reported up to 23% nerve pain following operative repair through an extended lateral approach.\(^6\) Zwipp et al analyzed early postoperative complications in 453 ORIF (open reduction and internal fixation) cases and found wound necrosis in 6.7%, hematomas in 4.7%, soft tissue infections in 4.3%, and deep bone infections in 2.2% of cases.\(^36\) Minimally invasive approaches to fracture reduction and fixation such as entirely percutaneous technique, arthroscopically assisted technique, or external fixation have become popular because of the lower incidence of wound complications.\(^*\)

This study provides further evidence of a very low rate of complications, suggesting that percutaneous reduction and fixation with screws alone decreases the secondary soft

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*References 2, 5, 9, 10, 16, 18, 26, 29, 31, 33.*
tissue injury and decreases the need for secondary procedures. In contrast to many other studies, the current study included all Sanders-type calcaneal fractures. All operatively treated calcaneal fractures in our institute were treated with this technique. From this cohort of relatively more severe calcaneal fractures, we had a 1% superficial infection rate, a 0.9% deep infection rate, a 6.5% subtalar arthrosis rate, and 9.3% total screw removal rate. Other authors have also reported low complication rates after minimally invasive approaches. Chen et al reported an operative technique similar to this study with the addition of injected calcium sulfate cement grafting and found a superficial infection rate of 2.6% without deep infection. Schepers et al and Tomsen et al performed percutaneous reduction after applying an external distractor followed by percutaneous fixation with screws. Schepers et al reported superficial infection in 11%, deep infection in 3%, and subtalar arthrosis in 15% of cases, whereas Tomsen et al reported superficial infection in 5%, deep infection in 8%, subtalar arthrosis in 5%, and screw removal in 46%. Arastu et al used a minimally invasive reduction and fixation technique using threaded K-wires and Steinman pins in intra-articular calcaneal fractures and excluded Sanders type 4 fractures. At a mean follow-up of 14.9 months, they found a 3% rate of superficial infections, and no deep infections or subtalar fusions were reported.

The radiographic analysis demonstrated that Bohler angle, calcaneal facet height, and calcaneal width were significantly improved between preoperative and immediate postoperative radiographs, but the angle achieved was still less than normal, indicating that the tuberosity was not completely repositioned in these cases. In addition, there was an average some settling of Bohler angle on follow-up films. Although it would be expected that open reductions would more effectively restore angles than percutaneous reductions and that plates should better maintain reductions than screws alone, similar results have been seen in some series using these techniques. Loucks et al and Shuler et al studied extensive open approaches and found that the angle was increased with operative reduction by 16.5 and 13.5 degrees, respectively, and a subsequent collapse on average of 7 degrees and 5 degrees, respectively. Dewall et al found a postoperative Bohler angle improvement of 22.4 degrees in the open approach group with a loss of 4 degrees at 4 months’ follow-up. This study demonstrated an increase of 24.1 degrees postoperatively, with a comparable angle collapse of 4.9 degrees at the 3-month follow-up. This study compared immediate postoperative non-weight-bearing radiographs with 3-month weight-bearing radiographs. It is also possible that more settling occurred in some cases after the 3-month radiographs used for the measurements in this study.

Measurement techniques such as Bohler angle provide a means to assess the overall return of heel height but do not address the quality of joint reduction. It was indicated from our data that the Bohler angle measured at both immediate postoperative and at 3 months postoperative did not correlate with postoperative activity, VAS pain score, postoperative stiffness, ability to return to work, screw complication, or late subtalar arthritis or fusion. Previous reports have lacked an assessment of what many believe to be a very important goal of surgical reduction: articular congruity which may correlate with clinical outcome and posttraumatic osteoarthritis. A postoperative CT was obtained the day following surgery in 50 of 153 patients at the discretion of the treating surgeon to assess for quality of reduction and position of the hardware. There was a gradual evolution toward less postoperative CT as experience with the technique increased. The measurement technique described in this study can be applied to both preoperative and postoperative CT scans as it focused on only the widest gap and was unaffected by fracture pattern, length, or a change in the angle from reduction. It provided a 3-dimensional assessment of articular displacement, which may be an advantage over standard plain radiographic assessments. In this series, the CT measurement technique showed significant postoperative improvement in the summation of gap(s) and step in the posterior talocalcaneal and calcaneocuboid joints but significant displacement remained. Although the clinical significance of initial and residual displacement is not fully known, displacement on both pre- and postoperative CT correlated with postoperative function level, VAS pain score, late arthritis, and subtalar fusion rate. In future studies, it may be more practical to measure the posterior facet displacement only. Further study of this technique is necessary, and we are currently conducting an observer reliability study.

This study found that most of the patients had no pain or only mild pain at the final follow-up. There was also a significant correlation between smoking and postoperative function, postoperative pain, postoperative stiffness, and ability to return to work. Smoking has previously been found to correlate with chronic pain syndrome, which includes chronic back pain, joint pain, head pain, and pain all over the body. Smoking may exacerbate pain via a postoperative feedback loop. Smokers were reported to have lower rehabilitation completion rate, greater opioid use, more anxiety, and more depression. These issues in smokers may result in worse postoperative function, pain, stiffness, and return to work found in the current study.

There are weaknesses of this study mostly due to the retrospective nature of the study including short and incomplete follow-up and lack of a concurrent control group treated by alternate techniques. The low rate of late complications such as subtalar arthrosis could be, in part, attributed to inadequate follow-up. In addition, the sensitivity of the imaging studies used in this study may not cover the entire spectrum of abnormal findings. Changes in calcaneal alignment including Bohler angle may occur beyond 3
months, and two-thirds of patients did not have postoperative CT scans. The CT measurement technique used in this study was also preliminary and requires further study. It was an attempt to 3-dimensionally measure displacement in a way that has not previously been done.

In conclusion, this study on calcaneal fractures reduced percutaneously and fixed with screws alone presents the results of a large number of consecutive nonselected cases that represent the range of calcaneal fractures seen at our institution. The complication rate was very low and the technique restored heel height and width similar to that reported in some previous studies. This study found that most of the patients had no pain or only mild pain at the final follow-up. The clinical significance of these residual displacements is uncertain but the study suggests some correlation of the CT articular displacement with outcome.

### Appendix

| Table A1. Logistic Regression Analysis for Factors That May Have Influenced Operative Outcome. |
|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| P Value                                           | Postoperative                                    | Postoperative                                    | Ability to                                        | Screw                                           | Subtalar Fusion or                                |
|                                                  | Activity                                         | VAS Score                                         | Return to                                        | Complication                                    | Late Stage Arthritis                              |
| Smoking                                          | <.01*                                            | P .05*                                           | <.01*                                           | >.05                                            | >.05                                             |
| Preoperative Bohler angle                        | >.05                                             | >.05                                             | >.05                                             | >.05                                            | <.05*                                            |
| Immediate postoperative Bohler angle             | >.05                                             | >.05                                             | >.05                                             | >.05                                            | >.05                                             |
| 3 months postoperative Bohler angle              | >.05                                             | >.05                                             | >.05                                             | >.05                                            | >.05                                             |
| Preoperative CT score                            | <.05*                                            | >.05                                             | >.05                                             | >.05                                            | <.05*                                            |
| Postoperative CT score                           | >.05                                             | P .05*                                           | >.05                                             | >.05                                            | >.05                                             |
| Work compensation                                | >.05                                             | >.05                                             | >.05                                             | >.05                                            | >.05                                             |
| Open injury                                      | >.05                                             | >.05                                             | >.05                                             | >.05                                            | >.05                                             |
| Sander classification                            | >.05                                             | >.05                                             | >.05                                             | >.05                                            | >.05                                             |

Abbreviations: CT, computed tomography; VAS, visual analog scale.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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