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Early Minimally Invasive Percutaneous Fixation of Displaced Intra-Articular Calcaneal Fractures With a Percutaneous Angle Stable Device

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A R T I C L E I N F O

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A B S T R A C T

The Minimally Invasive Reduction and Osteosynthesis System® (MIROS) is a percutaneous angle stable device for the treatment of fractures. The aim of the present study was to evaluate the clinical and radiographic results of an early minimally invasive osteosynthesis with the MIROS device. A total of 40 consecutive patients were treated for an intra-articular fracture of the calcaneus. We evaluated the clinical and radiographic outcomes after treatment of intra-articular calcaneal fractures with the MIROS hardware. Soft tissue damage was noted. The patients completed the American Orthopaedic Foot and Ankle Society survey at 12 and 24 months and underwent radiologic evaluations. A statistically significant association between the American Orthopaedic Foot and Ankle Society score and type of soft tissue lesion. A Sanders type II, III, and IV fracture was found in 15, 20, and 15 of 50 fractures, respectively. Postoperatively, restoration of the posterior facet was reached in 13 of 15, 18 of 20, and 11 of 15 with a type II, III, and IV fracture, respectively. The American Orthopaedic Foot and Ankle Society scale mean score was 85 at the final follow-up visit. No significant association was found between the score and the preoperative variables ($p > .09$), although patients with bilateral fractures had a significantly lower score. The MIROS device for early treatment of intra-articular calcaneus fractures resulted in excellent clinic and radiologic results. The standardized technique we have reported, with the elastic wires acting as a girder for the fractured and displace subtalar joint and the collapsed lateral calcaneal wall, has permitted early weightbearing with positive stimuli for the bone healing. The drainage effect of the percutaneous wires likely prevented compartment syndrome when applied within the first hours after the trauma.

The calcaneus is the most commonly fractured tarsal bone, accounting for 75% of displaced intra-articular fractures (1). The treatment of complex intra-articular calcaneal fractures is still controversial (2). Evidence from previous studies has shown that anatomic restoration of the calcaneal shape and joint congruity is associated with higher functional scores (3–6), a lower incidence of post-traumatic subtalar arthritis, and a lower rate of secondary subtalar fusion (7) when treating these fractures. When performing open reduction and internal fixation, a frequent complication has been soft tissue trauma with disturbance of wound healing and necrosis, in particular over the lateral calcaneal wall exposed during surgery (8). The rate of skin necrosis has varied from 2% to 11%, with the soft tissue infection rate ranging from 1.3% to 7% after an extended lateral approach, with reported wound complications in 25% of patients (3,6,8–10).

To overcome the soft tissue problems in the treatment of complex calcaneus fractures, some investigators have proposed minimally invasive reduction and fixation (5,11,12). Compared with open procedures, minimally invasive techniques can guarantee good reduction with fewer complications. The Minimally Invasive Reduction and Osteosynthesis System® (MIROS; Technovare Europa Trading, Anagni, Frosinone, Italy) is a recently introduced angle stable device for the treatment of fractures. It has shown good results in osteosynthesis of complex proximal humerus fractures in the elderly with severe osteoporosis (14). To achieve the best results, timing is an important factor, with surgery ideally performed within 3 to 5 days, especially in percutaneous or minimally invasive procedures (13). It allows for correction of angular displacement and fixation of fracture fragments using elastic Kirschner wires locked in a metallic clip placed externally to the skin.

In our department, in the previous 4 years, we have used the MIROS device to treat displaced intra-articular calcaneus fractures in

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43 consecutive patients, 10 of whom had bilateral fractures, for a total of 53 fractures. The aim of the present prospective cohort study was to evaluate the clinical and radiographic results of early minimally invasive osteosynthesis of the calcaneum using the MIROS device.

Patients and Methods

From January 1, 2008 to December 31, 2011, all patients admitted with a diagnosis of unilateral or bilateral displaced intra-articular fractures of the calcaneus were considered for inclusion in the present study. The included Current Procedural Terminology diagnostic codes were 825.0 and 825.1 (2012 "International Classification of Diseases, 9th Revision, Clinical Modification" diagnosis code). The inclusion criteria were the diagnosis of a closed or open displaced intra-articular fracture of the calcaneus (posterior articular facet step-off of >2 mm, significant shortening, loss of height, and widening of the calcaneus [i.e., decreased Böhler's and Gissane's angles], valgus deviation >10°, varus deviation >5°) of Sanders type II, III, or IV; recovery of the patient within 12 hours from the time of trauma; and patient age 18 years or older.

The exclusion criteria included a history of previous fractures or surgeries in the affected lower limb, a previous diagnosis of neurologic or vascular diseases affecting the lower extremities, and/or local vascular or neural complications associated with the injury.

All patients admitted to the hospital with a diagnosis of a calcaneal fracture were examined by 1 of 2 of us (A.B., S.C.), who first classified the soft tissue damage in accordance with the classification system of Tscherne and Oestern (15). In the emergency department, all patients underwent standard radiographic assessment, including the calcaneus lateral, axial, and Brodén views at 20° and 40°, and bilateral computed tomography for fracture classification and preoperative planning (16). The fractures were classified using the Sanders (4) scale, with the letters A, B, and C denoting the location of the fracture lines within the posterior facet. Type A represents a lateral fracture line, type B a fracture line through the middle of the facet, and type C a medial fracture line adjacent to the sustentaculum tali. The 2 of us (A.B., S.C.) involved in classifying the soft tissue damage and the fracture pattern were trained by repeating the evaluation 3 times per fracture.

After hospitalization, the study participants gave their informed consent for inclusion in the present study and for the operation, which was performed 6 to 12 hours (after the recovery) in 36 patients (83.72%) and in 7 patients within 4 days, always by the same 2 surgeons (A.B., P.C.). The fitness for surgery was assessed using the American Society of Anesthesiologists grade (17). Of the 43 patients, 26 (60.47%) were American Society of Anesthesiologists grade I, 10 (23.25%) grade II, and 4 (9.30%) were grade III. The duration of surgery and the fluoroscopic time were recorded.

The study participants underwent clinical evaluation with standard radiographs at 3, 6, and 12 weeks postoperatively. At 12 and 24 months postoperatively, the patients were assessed by the same 2 examiners (A.B., S.C.), and the American Orthopaedic Foot and Ankle Society (AOFAS) ankle hindfoot scale (18,19) was administered to quantify the functional outcomes. The scale measures the intensity of pain, function (including restraint of activities and the need for support with an orthosis), maximum walking distance, abnormality of gait, sagittal mobility (flexion and extension), hindfoot mobility (inversion and eversion), the anteroposterior and varus–valgus stability of the ankle and hindfoot, and alignment of the foot and ankle. The scores for each item were summed, providing a total from 0 to 100. Total scores of 90 to 100 were classified as excellent, from 80 to 89 as good, and from 70 to 79 as fair; a total score less than 70 was considered a poor result.

At the final follow-up evaluation, a clinical assessment was performed (A.B. or S.C.) and a full radiographic assessment completed, including standard views, hindfoot alignment view (20), lateral and dorsoplantar weightbearing radiographs (21), and a 20° Brodén view (16). The 2 examiners (A.B., S.C.) judged (3 times each for each measurement) the reduction of the calcaneal shape considering the Böhler tuberosity joint angle (in angular degrees), the crucial Gissane angle (in angular degrees), and the height and width of the calcaneus (in millimeters) (20).

Standard Operative Technique

After a carbocaine lower limb block, the patient was placed in a lateral decubitus position. No tourniquet was used. For antibiotic prophylaxis, 2 g of cefazolin was administered intravenously 30 minutes preoperatively and at 3 and 12 hours postoperatively. Before inserting the Kirschner wires, attempts were made to reduce the fracture by manipulation. A lateral incision of 2 cm was made as an access entry point for insertion of a periosteal elevator (Fig. 1). The elevator was moved to the lower posterior articular surface, and the articular fragment was elevated into anatomic configuration. Next, 1 wire was inserted from the same direction of the major axis of the calcaneus, parallel to the reduced posterior facet, and pulled until the cuboid, because the purchase in the calcaneus alone might be not sufficient. The same procedure is used with a second wire, parallel to the first. If necessary, additional elevation of the articular posterior facet can be done using the 2 wires as elevators, with the cuboid as a fulcrum. In this configuration, the 2 wires act as an inferior girder for the depressed articular fragment, and correction of Böhler's angle is obtained (Fig. 2). Reduction of the posterior facet should be checked on the Brodén radiographic views, and reduction of the calcaneus can be verified from the lateral radiographic views. The first 2 wires can then be locked in the pin and clip fixator. Next, the heel was compressed to impact the lateral wall, reduce the calcaneal width, and prevent lateral impingement of the peronei tendons. Acting on the lateral wall, 2 wires were introduced and pulled until reaching the sustentaculum tali, which will usually not have been dislocated in most calcaneal fractures because of its attached ligaments. The other 2 wires will act as 2 lateral girders to sustain the collapsed wall. The second 2 wires can now be locked in the metallic clip (Fig. 3). Additional fragments can be fixed with other wires, which should be positioned conically into the talus and cuboid and bent to lock them in 1 of the 2 metallic clips or in an additional metallic clip. As an alternative, bone fragments that could cause lateral or medial impingement can be percutaneously removed by osteotomy. Finally, 2 or more metallic clips were fastened with connecting wires to improve the stability of the whole system (Fig. 3).

Postoperative Care

Postoperatively, a simple dressing was applied without a cast. Physical therapy with passive and active range of motion at the ankle, subtalar, and midtarsal joints was initiated the day after surgery under the supervision of a physiotherapist. The patients were encouraged to perform their exercises at least 30 minutes twice a day, in addition to isotonic and isometric exercises of the leg. The patients were allowed to walk with 2 crutches 2 days after surgery but were instructed to remain non-weightbearing. Partial weightbearing was begun in the fourth postoperative week and increased to full weightbearing at the eighth postoperative week. The pins were removed once the fracture was considered healed, usually 70 days after surgery, without any anesthesia in an outpatient procedure. The fracture was considered healed when the lines of the fracture were not visible on standard radiographs. In addition, fracture stability and healing were consistently evaluated by testing the inversion, eversion, flexion, and extension of the ankle under fluoroscopy. This was performed by the 2 surgeons involved in evaluating the clinical and radiologic assessments.

Statistical Analysis

The statistical analysis was performed using Statistical Package for Social Sciences software, version 16.0 (SPSS, Chicago, IL). The intra- and interobserver agreement was determined using the κ statistic, with the level of significance set a priori at $p < .01$. Interpretation of the κ statistic was performed as described by Landis and Koch (22). Agreement was considered excellent if the κ statistic was from 0.81 to 1.0, high if it was 0.61 to 0.80, moderate if 0.41 to 0.60, fair if 0.21 to 0.40, and poor if 0.20 or less (22). Fisher's exact test was used to compare the proportions and Student's t test for average values. Student's t test, paired, was used for average values.

We defined statistical significance at the 5% ($p \leq .05$) level. Multiple regression analysis was performed to identify potential associations between dependent variables

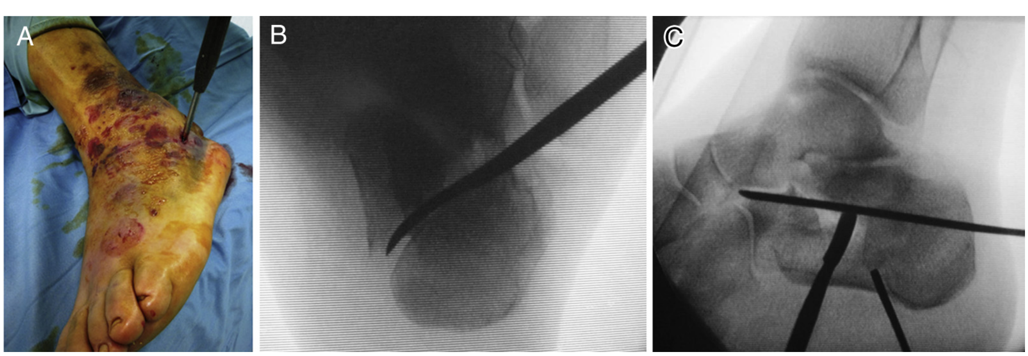

Fig. 1. (*A* and *B*) The periosteal elevator was inserted through a 2-cm incision in the lateral aspect of the calcaneus to reduce the posterior facet. (*C*) The first elastic wire was inserted to stabilize the articular fragment.