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Original Research

Outcome of Minimally Invasive Open and Percutaneous Techniques for Repair of Calcaneal Fractures: A Systematic Review

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ABSTRACT

Percutaneous and minimally invasive open techniques for the treatment of calcaneal fractures are now frequently used with good results, although a comparison between these different techniques has not yet been performed. The aim of the present review was to search for studies evaluating the outcomes of patients after treatment with percutaneous and minimally invasive open techniques for calcaneal fractures. A search was performed using PubMed/MEDLINE, Embase, and the Cochrane Library. Studies from the previous 15 years in English were included. Data on the Sanders classification, operation technique, infection rate, American Orthopaedic Foot and Ankle Society ankle-hindfoot score, radiographic evaluation, and follow-up were extracted. The techniques were divided into 4 groups: minimally invasive open, percutaneous reduction and screw osteosynthesis, external fixation, and other. Forty-six studies were included, with 1776 patients and 2018 calcaneal fractures. Of the 2018 fractures, 924 (46%) were classified as Sanders II, 558 (28%) as Sanders III, and 245 (12%) as Sanders IV; the fractures of 291 patients(14%) were not classified or were classified as complete extra-articular. Of the 46 studies, 15 used a minimally invasive open technique, 19 evaluated the outcome of percutaneous reduction and screw osteosynthesis, 10 investigated the results of an external fixation system, and 2 studies used other operative techniques. The median infection rate was 3% (range 0% to 33%). The median American Orthopaedic Foot and Ankle Society ankle-hindfoot score was 83 (range 67 to 94). The median angle of Böhler postoperatively was 24° (range 14° to 35°) and had increased after operative treatment, with a median of 16° (range 0° to 39°). The percutaneous reduction and screw osteosynthesis and minimal invasive open technique resulted in significantly better outcomes compared with external fixation and other techniques. In conclusion, percutaneous reduction and screw osteosynthesis and minimal invasive open techniques have the best outcomes for the minimal invasive open surgical treatment of calcaneal fractures.

The frequency of fractures of the calcaneal bone has been estimated at 2% of all fractures, and 75% of these will be intra-articular fractures. Such intra-articular fractures are particularly at risk of complicated outcomes and a prolonged recovery. Approximately 20% of patients with intra-articular calcaneal fractures will not able to return to work within 1 year, with the associated high social impact and high economic costs (1,2). The ideal treatment of calcaneal fractures remains controversial (3,4). Operative treatment with open reduction and internal fixation (ORIF) has been performed for decades and is currently the standard treatment option. This approach can, however, be complicated by wound infection, wound dehiscence, flap devascularization, and injury to the sural nerve (5,6). The rate of complications has been reported at 15% to 25% and the infection rate at 0.4% to 27% (7,8). Previous studies revealed that surgical treatment has good results; however, to reduce the risk of soft tissue complications, interest has arisen in percutaneous reduction and screw osteosynthesis and minimally invasive open techniques (4,9–11). After the first percutaneous operation by the German surgeon Westhues in 1934, a considerable number of percutaneous and minimally invasive open techniques have been used to treat calcaneal fractures (12). Although these techniques can minimize the incidence of soft tissue complications, one disadvantage might be the risk of incomplete reduction, especially in difficult intra-articular calcaneal fractures. An incongruence in the posterior facet of the subtalar joint and failure to restore the angle of Böhler have been frequently mentioned as important predictors of outcome after operative treatment of calcaneal fractures (8,13,14). Based on several studies with percutaneous techniques, Rammelt et al (13) concluded in 2004 that percutaneous fixation of displaced calcaneus fractures produces good to excellent results in properly selected patients with less severe

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fracture patterns and that the quality of joint reduction should be directly visualized to avoid problems in subtalar joint motion. At present, no review has been reported comparing different minimally invasive open and percutaneous techniques (3). The aim of the present review was therefore to search for published studies of percutaneous reduction and screw osteosynthesis and minimally invasive open techniques for calcaneal fractures and to compare the radiologic reduction parameters and patient-reported outcome measures as outcome variables.

Materials and Methods

Published Data Search

A systematic search term was constructed with the medical subject heading (MeSH) terms: percutaneous [All Fields] AND ("calcaneus"[MeSH Terms] OR "calcaneus"[All Fields]) AND ("fractures, bone"[MeSH Terms] OR ("fractures"[All Fields] AND "bone"[All Fields]) OR "bone fractures"[All Fields] OR "fracture"[All Fields]). The databases PubMed/MEDLINE, Embase, and Cochrane Library were searched. All abstracts found in the search were screened. Studies from the previous 15 years in English, regardless of the level of evidence, were included. Studies before 1999 and studies published in other languages were excluded. Studies that did not evaluate calcaneal fractures, that had studied calcaneal fractures in children, or that did not concern percutaneous reduction and screw osteosynthesis or minimally invasive open techniques were excluded. The reference lists of the reports retrieved by the initial search were checked manually for additional studies not found by the electronic search. Data were extracted from these studies.

Operative Technique

For the present review, the studies were divided into 4 groups. The first group included studies using a minimally invasive open technique. In this group, a small incision was made that differed from the standard lateral incision for ORIF to reduce soft tissue complications. Studies using a sinus tarsi approach were also included in this group. The second group included all studies using percutaneous reduction and screw osteosynthesis. The third group consisted of studies using an external fixation technique as the end-treatment option for calcaneal fractures. Studies with minimally invasive techniques other than these were included in group 4. The additional use of arthroscopy or bone augmentation for the treatment of the calcaneal fracture during the minimally invasive open or percutaneous technique was noted if described in the report.

Classification of Fractures

For the present review, the Sanders classification, determined from computed tomography (CT) findings, was used as the fracture classification system. Almost all included studies reported this classification, and this information was extracted for the present review to rank the fractures from the included studies. The Sanders classification is determined by the number and location of articular fracture fragments and is scored on coronal CT scans. All nondisplaced articular and extra-articular fractures, regardless of the number of fracture lines, were considered type I fractures. Type II, III, and IV fractures involved 2-, 3-, or 4-part dislocated fractures determined by the number and location of the primary fracture lines (15). Calcaneal fractures were also classified as closed or open. According to the published data, open calcaneal fractures will develop more soft tissue complications and worse outcomes (16). In the present review, the number of open fractures in the included studies was noted if reported.

Patient-Reported Outcome Measures

Most studies evaluated the outcome of calcaneal fractures after treatment using validated patient-reported outcome measures (PROMs). The PROMs used in these studies included the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score, the Maryland Foot Score, the Foot and Ankle Disability Index, the Medical Outcomes Study Short-Form 36-item survey, and the visual analog scale. Most included studies used the AOFAS ankle-hindfoot score, which was therefore summarized from the included articles (17,18). The AOFAS ankle-hindfoot scores were graded as excellent (>90), good (>80), fair (>70), or poor (<70) (7,19).

Radiographic Evaluation

When reported, the following pre- and postoperative radiographic parameters on conventional radiographs were recorded: Böhler's angle, Gissane's angle, the length and height of the posterior facet of the calcaneal bone, and the calcaneal width. The step-off in the posterior facet in the subtalar joint and the subtalar joint axis were noted, if they had been analyzed in the included studies on CT scans (6). The step-off was used to evaluate the congruency of the subtalar joint and the reduction of the fracture after surgery.

Statistical Analysis

The data were analyzed using SPSS, version 20 (IBM Statistics; IBM, Armonk, NY). The data are presented as the mean ± standard error of the mean when the Levene test displayed parametric distribution or as the median and range when it did not. A comparison of the radiographic and functional outcome parameters was performed using 1-way analysis of variance or the Kruskal-Wallis test, depending on the distribution of the data. The Bonferroni or Dunn post hoc correction was performed for results between the different operating techniques. The Pearson correlation test was used to find correlations. A p value $< .05$ was considered statistically significant.

Results

Included Studies

The initial search revealed 100 reports, 33 of which were included in the present review. Another 13 reports were found by manually checking the references. Thus, the review included 46 reports that had evaluated the outcome of percutaneous reduction and screw osteosynthesis and minimally invasive open techniques for calcaneal fractures. The 46 studies included 1776 patients with 2018 calcaneal fractures, with a median of 25 patients in each study (Table 1). Fifteen studies reported the results of a minimally invasive open technique for surgery of the calcaneal bone (7,8,11,20–31). Nineteen evaluated the outcome of percutaneous reduction and screw osteosynthesis (5,6,16,19,32–46). Ten studies investigated the results of an external fixation system (1,47–55). Two studies used other operating techniques (56,57). Walde et al (57) reported the outcome after Kirschner wire fixation for the treatment of dislocated calcaneal fractures, and Kesemenli et al (56) used a button and suture fixation device for the treatment of calcaneal fractures. Of all the fractures, 924 (46%) were classified as Sanders II, 558 (28%) as Sanders III, and 245 (12%) as Sanders IV. In 291 cases (14%), the patients' fractures were not classified using the Sanders classification or were classified as completely extra-articular. In the study by DeWall et al (32), a selected group of patients did not undergo CT, leaving some patients with unclassified fractures. All the studies together reported 65 patients with an open calcaneal fracture (3.2%). In 7 studies, arthroscopy was used to inspect the subtalar joint (8,11,25,33,39,42). Five studies used bone augmentation to treat the calcaneal fracture (5,7,20,34,35). In the study by Arastu et al (20), augmentation was used in only 23% of all patients.

Outcome

The outcomes reported by the 46 included studies (1,5–8,11,16,19–57) are listed in Table 2. The median follow-up period was 24 (range 3 to 102) months. The median infection rate reported in 43 of the 46 included studies was 3% (range 0% to 33%) (5–8,11,16,19–39,41–46,48–57). A variety of PROMs were used in the 46 included studies, but 20 of the 46 used the absolute AOFAS ankle-hindfoot score to evaluate the outcome (1,5,7,16,19,21,23,30,31,33,37,39,41,42,45,47,49–51,56). The median AOFAS score was 83 (range 67 to 94). The weighted AOFAS ankle-hindfoot score determined from the number of included patients gave similar results. Regarding the radiologic evaluation, 30 studies used conventional radiographs to measure the angle of Böhler (1,5–8,11,16,19,20,23,24,26,27,29,31,32,34,38–42,45,48,49,51,52,56,57). Twelve studies used conventional radiographs to measure the angle of Gissane (6,11,24,27,29,40,41,46,49,51,52,56). The median preoperative angle of Böhler measured was 5° (range −15° to 25°) compared with a postoperative angle of 24° (range 14° to 35°). The median increase in the angle of Böhler after operative treatment was 16° (range 0° to 39°).