Subtalar Fusion After Displaced Intra-Articular Calcaneal Fractures: Does Initial Operative Treatment Matter?

By Craig S. Radnay, MD, MPH, Michael P. Clare, MD, and Roy W. Sanders, MD

Investigation performed at the Orthopaedic Trauma Service, Florida Orthopaedic Institute, Tampa, Florida

Background: Many patients with displaced intra-articular calcaneal fractures require subtalar arthrodesis for the treatment of posttraumatic arthritis. We hypothesized that patients who underwent initial operative treatment would have better functional outcomes as compared with those who underwent initial nonoperative treatment before undergoing a subtalar arthrodesis.

Methods: A consecutive series of sixty-nine patients with seventy-five displaced intra-articular calcaneal fractures underwent subtalar arthrodesis for the treatment of painful posttraumatic subtalar arthritis. Group A comprised thirty-four patients (thirty-six fractures) who initially were managed with open reduction and internal fixation and subsequently underwent in situ subtalar fusion at an average of 22.6 months later. Group B comprised thirty-five patients (thirty-nine fractures) who initially were managed nonoperatively and had development of a symptomatic painful malunion and subsequently underwent a subtalar distraction arthrodesis. The two groups were similar with respect to age, sex, injury mechanism, and smoking status. All complications were noted and functional outcomes were assessed at a minimum of forty-eight months after fusion.

Results: All sixty-nine patients were available for follow-up. The average duration of follow-up was 62.5 months for Group A and 63.5 months for Group B. There were three nonunions of the subtalar fusion requiring revision in each group. Group A had fewer postoperative wound complications and had significantly higher Maryland Foot Scores (90.8 compared with 79.1; $p < 0.0001$) and American Orthopaedic Foot and Ankle Society ankle-hindfoot scores (87.1 compared with 73.8; $p < 0.0001$) than did Group B.

Conclusions: In our study population, better functional outcomes and fewer wound complications were associated with subtalar fusion for the treatment of symptomatic posttraumatic subtalar arthritis after initial open reduction and internal fixation of a displaced intra-articular calcaneal fracture as compared with subtalar arthrodesis for the treatment of symptomatic posttraumatic subtalar arthritis secondary to calcaneal malunion following initial nonoperative treatment. Initial open reduction and internal fixation restores calcaneal shape, alignment, and height, which facilitates the fusion procedure and establishes an opportunity to create a better long-term functional result. We recommend open reduction and internal fixation for the treatment of displaced intra-articular calcaneal fractures when appropriately indicated.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

The treatment of displaced intra-articular calcaneal fractures remains a challenge for the orthopaedic surgeon. These fractures are complex injuries that are associated with considerable damage to bone, cartilage, and the surrounding soft tissues. Although recent studies have generally supported acute operative treatment[1-8], controversy continues to surround the issue[9-11]. Inadequate or inappropriate treatment of displaced intra-articular calcaneal fractures frequently results in persistent pain in the foot, loss of hindfoot motion, angular deformity, and disability, and many patients with these fractures require a late subtalar arthrodesis. Because of the difficulty of restoring the talocalcaneal relationship following a

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calcaneal malunion, patients with a displaced calcaneal fracture may derive better long-term results from initial operative treatment designed to restore and preserve the architecture of the hindfoot. The purpose of the present study was to evaluate the intermediate to long-term results for patients who underwent a late subtalar arthrodesis for the treatment of painful posttraumatic subtalar arthritis following a displaced intra-articular calcaneal fracture. Our hypothesis was that patients who underwent primary operative treatment of the fracture would have better outcomes after late subtalar fusion than those who initially were managed nonoperatively.

Materials and Methods

The present study was a retrospective review of a consecutive series of patients who had sustained a displaced intra-articular calcaneal fracture and subsequently had undergone late subtalar arthrodesis. A database search was performed to identify patients who had been managed, by a single surgeon, with late subtalar arthrodesis after having sustained a displaced intra-articular calcaneal fracture.

Between January 1, 1989, and December 31, 2001, the senior author (R.W.S.) performed seventy-five consecutive subtalar arthrodeses in sixty-nine patients for the treatment of posttraumatic subtalar arthritis following a displaced intra-articular calcaneal fracture. All patients had severe subtalar pain, difficulty walking on uneven surfaces, decreased subtalar motion, and radiographic evidence of degenerative changes in the subtalar joint. Thirty-four patients (thirty-six fractures) initially had been managed surgically by or under the direct supervision of the senior surgeon with open reduction and internal fixation (Group A). Thirty-five patients (thirty-nine fractures) initially had been managed nonoperatively at an outside institution (Group B). Twenty-four additional malunions in twenty-three patients who had had previous attempts at operative fixation of the fracture elsewhere were excluded from the study because they had not been initially managed nonoperatively and had not received standardized reduction and internal fixation as compared with those who had undergone the operative procedures at our institution.

Data on the seventy-five fractures were collected from medical records, patient interviews and examinations, and radiographic analyses. Information was gathered on pain, function, and overall satisfaction. Computed tomographic and radiographic analyses were used to classify the calcaneal fracture type according to the system of Sanders et al.[5-7] for Group A and the calcaneal malunion type according to the system of Stephens and Sanders[12] for Group B.

Forty-five (60%) of the seventy-five fractures occurred in patients who smoked, including twenty-two (61%) of the thirty-six fractures in Group A and twenty-three (59%) of the thirty-nine fractures in Group B. While cessation of smoking was encouraged and patients were informed of the increased surgical risks, many disregarded this advice. With informed consent obtained, smoking was not a contraindication to surgery in our series.

All patients in both groups were managed initially according to standard treatment protocols for operative[6] or nonoperative fracture care, as described in detail in previously published reports[6,7,12-15]. In all patients, the subtalar arthrodesis was performed with use of an extensile lateral approach to the calcaneus, with the raising of a full-thickness subperiosteal flap. In Group A, implants were removed from the calcaneus, and, after débridement of the remaining and damaged joint cartilage, an in situ fusion was performed with use of cancellous allograft chips and 8.0-mm cancellous cannulated screws in a lag mode (DePuy ACE, a Johnson and Johnson Company, Warsaw, Indiana). In Group B, the lateral wall exostosis was resected with use of an oscillating saw with a thin 1-in (2.54-cm)-wide blade (Synthes, Paoli, Pennsylvania). Thereafter, treatment was specific to the type of malunion encountered. In addition to the exostectomy and subtalar fusion that were performed for type-II malunions, a Dwyer-type calcaneal osteotomy, designed to correct axial malalignment of the hindfoot, was performed for type-III malunions[12,15]. After débridement of the joint and the sinus tarsi, lateral fluoroscopic images were made to determine the correct height needed (confirmed by anatomic alignment of the talar head with the navicular, indicating restoration of the medial column), the normal angle of talar declination, and the talocalcaneal angle[15]. When possible, the lateral wall of the calcaneus, which had been resected in one piece, was placed in the subtalar joint space and was used to maintain height, with additional cancellous allograft placed in the sinus tarsi. If height could not be adequately restored with use of the lateral wall, then a tricortical allograft was fashioned to fit the subtalar joint defect instead. Arthrodesis was then performed with use of 8.0-mm cancellous cannulated screws in a lag mode (DePuy ACE, a Johnson and Johnson Company).

Methodology Review

Patients were assessed clinically at a minimum of forty-eight months after surgery with use of the Maryland Foot Score[16] and the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score[17]. These scores were selected because of their common use in outcomes evaluation in the foot and ankle literature, with the ankle-hindfoot score being a validated score. Patients were considered to have successful union at the fusion site if they were able to walk comfortably without assistance, if there was no hindfoot motion on clinical examination, and if there was radiographic evidence of trabeculation across the fusion site. Patients who did not meet all three of these criteria were further examined with fluoroscopy to determine union. At the time of the study, a computed tomography scan was not routinely performed to determine union at the fusion site.

All clinical notes were reviewed retrospectively and a questionnaire, based on the ankle-hindfoot scores, was completed by the patients before surgery and at the time of the latest follow-up to create the preoperative and postoperative database. These data were obtained by a research nurse who was blinded to the purpose of the study. Questions focused on pain severity, activity level, work status, and smoking routine. Because the scores were used to assess patients who had had a subtalar arthrodesis, modifications were made to the Maryland Foot Score and ankle-hindfoot score by eliminating the sub-

talar joint motion component of the score. Thus, the maximum achievable score for a patient who had had a subtalar arthrodesis was 99 (rather than 100) for the Maryland Foot Score and 94 (rather than 100) for the ankle-hindfoot score[17]. In addition, data were collected on the mechanism of injury, hindfoot alignment, and complications.

Statistical Methods

Descriptive statistics were used to compare patient characteristics, treatment data, and outcomes. Chi-square and Fisher exact tests were used to test the differences between the two samples in terms of categorical data, and t tests were used to test for differences in terms of continuous data. The continuous outcomes of the two samples were examined for equality of variances; the Satterthwaite t test was used when the variances were significantly different as tested with the Folded F test. The level of significance was set as $p \leq 0.05$; the level of borderline significance was defined as $0.05 < p < 0.10$.

Sample Size and Power Calculations

Sample size was determined on the basis of recommendations for the magnitude of effect size[18]. In some research (e.g., studies conducted in applied settings or new areas of inquiry), effect sizes may be small because the phenomena under study are not under good experimental or measurement control. The smaller the effect size, the larger the sample required (other parameters being equal) to detect significant differences. With use of concepts and tables as reported by Cohen[18], a sample of seventy-five fractures (divided into two samples of thirty-six and thirty-nine fractures each) has at least 80% power (with a type-1 error of $p < 0.05$ [two-tailed test]) to detect moderate effects (effect size, 0.66), allowing for the detection of differences in mean values of continuous outcomes that are at least 0.66 standard deviation units, in which the standard deviation is the square root of the mean of the two variances.

Source of Funding

There was no external funding for this study.

Results

All sixty-nine patients (seventy-five fractures) were available for follow-up. The average duration of follow-up was 62.5 months (range, forty-eight to 141 months) for Group A and 63.5 months (range, fifty to 122 months) for Group B. The average age of the patients was 43.1 years (range, twenty-two to seventy-six years) in Group A and 46.4 years (range, twenty-five to seventy-four years) in Group B. Group A included twenty-seven men and seven women, and Group B included twenty-five men and ten women. Most injuries were originally the result of high-energy trauma. In Group A, twenty-nine fractures were caused by a fall from a height and seven injuries were sustained during a motor-vehicle accident. In Group B, twenty-nine fractures were caused by a fall from a height and ten injuries were sustained during a motor-vehicle accident. In addition, Group A included more fractures in patients with a Workers' Compensation claim (67%; twenty-four of thirty-six fractures) than Group B (44%; seventeen of thirty-nine fractures); this difference was of borderline significance ($p = 0.06$).

Originally, in Group A, there were eighteen Sanders type-II fractures, seventeen Sanders type-III fractures, and one Sanders type-IV fracture. Two patients had a bilateral fracture: one had a bilateral type-III fracture, and the other had one type-III fracture and one type-IV fracture. This latter patient underwent open reduction and internal fixation without a primary fusion at a time when the senior author was still limiting the treatment of type-IV fractures to open reduction and internal fixation alone.

In Group B, thirty-one feet had a type-II malunion and eight feet had a type-III malunion. Four patients had a bilateral malunion; two had a bilateral type-II malunion, one had a bilateral type-III malunion, and one had one type-II and one type-III malunion.

In Group A, the average interval between the initial open reduction and internal fixation and the subsequent subtalar arthrodesis was 22.6 months (range, nine to 106 months); in Group B, the average time between the injury and the subtalar fusion to treat a painful malunion was 16.4 months (range, six to 117 months). In Group B, several patients with polytrauma had been transferred to our institution without definitive treatment of the calcaneal fracture. These patients all had substantial deformity with displacement of the subtalar joint, lateral wall explosion, and subfibular impingement. In these cases, the fracture had already consolidated to such a degree that open reduction and internal fixation was not feasible. Operations were performed for these fractures when soft-tissue swelling was absent and the bone had healed enough to allow fixation, at a minimum of six months after the injury.

Thirty-three (92%) of the thirty-six arthrodeses in Group A and thirty-six (92%) of the thirty-nine arthrodeses in Group B resulted in initial union. There were three nonunions in each group. All six nonunions were treated with a second arthrodesis procedure, and in all cases a solid fusion was achieved. Following successful arthrodesis, the implants were removed from sixteen (44%) of the thirty-six feet in Group A and thirteen (33%) of the thirty-nine feet in Group B.

Delayed wound-healing (defined as superficial drainage and/or partial-thickness necrosis) was observed in only four (11%) of the thirty-six feet in Group A, compared with eleven (28%) of the thirty-nine feet in Group B; with the numbers studied, this difference was of borderline significance ($p = 0.08$).

Two (6%) of the thirty-six arthrodeses in Group A were in patients who required prolonged oral antibiotics for more than six weeks because of a soft-tissue infection, whereas eleven (28%) of the thirty-nine arthrodeses in Group B were in patients who required such treatment. This difference was significant ($p = 0.01$). No patient in Group A and only one patient in Group B had progression to a deep infection. This one patient underwent formal débridement and removal of infected bone, delayed wound closure, and six weeks of culture-specific antibiotic therapy and had not had a recurrence of infection as of the time of the 104-month follow-up.

Functional outcomes were assessed at a minimum of forty-eight months. The average Maryland Foot Score (and standard

deviation) was significantly higher for Group A (90.8 ± 5.00; range, 81 to 98) than for Group B (79.1 ± 15.3; range, 30 to 96) ($p < 0.0001$). The average AOFAS ankle-hindfoot score was significantly better for Group A (87.1 ± 5.9; range, 75 to 94) than for Group B (73.8 ± 15.1; range, 25 to 94) ($p < 0.0001$). With the numbers studied, no significant differences in the functional outcome scores could be detected among the different malunion types.

Discussion

The calcaneus is the most frequently fractured bone in the foot, accounting for 65% of tarsal injuries and approximately 2% of all fractures[6,19]. While the role of nonoperative treatment for undisplaced fractures is commonly supported in the literature[5-9,20-27], initial operative treatment of displaced intra-articular fractures is still not universally advocated[10,11,20,28-32]. Furthermore, patients can have development of painful posttraumatic subtalar arthritis that requires a fusion regardless of the initial form of treatment[13].

Surgical treatment of acute displaced intra-articular calcaneal fractures attempts to restore normal biomechanics to the hindfoot. Both Palmer in 1948 and Essex-Lopresti in 1952 stressed the need for reduction of these fractures, with poor functional results arising from incomplete reduction of the subtalar joint[22,23]. More recently, malalignment of as little as 1 mm has been shown to alter the forces across the posterior facet and to cause disturbances in gait[3,33,34]. Anatomic reduction of the calcaneus therefore attempts to recreate congruent subtalar and calcaneocuboid joints, to achieve a reduced lateral wall and peroneal tendons, and to restore calcaneal height, hindfoot alignment, and talar declination. Patients should expect to wear regular shoes, to exhibit a normal gait, and to remain pain-free for an extended period of time[5-8,19]. Sanders et al.[7], Zwipp et al.[27], Leung et al.[28], and Benirschke and Sangeorzan[24] all indicated that the best possible long-term treatment results occur after an anatomic open reduction and internal fixation with use of an extensile lateral approach, lag screw, and neutralization plate fixation.

Nevertheless, many surgeons still treat calcaneal fractures nonoperatively, either because of a lack of familiarity with the operative techniques or because they are concerned with potential complications[6,35-37]. Although nonoperative treatment eliminates the risks associated with surgical treatment, a symptomatic malunion often results when no attempt is made to restore calcaneal height and alignment. With a calcaneal malunion, typical pathologic findings include incongruity of the posterior facet and calcaneocuboid joint surfaces, resulting in posttraumatic arthritis; lateral calcaneal wall expansion, causing both heel widening and subfibular impingement of the peroneal tendons; loss of calcaneal height, decreasing ankle dorsiflexion; and displacement of the calcaneal tuberosity, with residual hindfoot malalignment and a varus deformity[12-14,38-40].

Treatment of the sequelae of calcaneal malunions includes isolated subtalar arthrodesis, lateral wall ostectomy, or both[40-45]. If there is loss of heel height, one may perform a subtalar distraction bone-block arthrodesis, first described by Gallie in 1943[46] and later modified by Carr et al.[38], to help restore hindfoot alignment. Myerson and Quill believed that the appropriate indications for this procedure included loss of >8 mm of heel height and radiographic evidence of anterior tibiotalar impingement[40]. Overall, the results of this technique have been favorable[21,38,40,47,48], with high rates of fusion and improvement in the talocalcaneal angle after surgery. However, Myerson and Quill[40] as well as Flemister et al.[13] cautioned against aggressive attempts to restore heel height as this may lead to hindfoot varus. In fact, Flemister et al. noted that, in the absence of lateral impingement, an in situ fusion had a more favorable outcome than distraction bone-block arthrodesis did[13]. Finally, most authors have agreed that varus malalignment of the hindfoot can be at least partially corrected with use of a lateral closing-wedge osteotomy[16,28,40,47,49].

Stephens and Sanders reported on a computed tomography classification system and treatment protocol for calcaneal malunions[12]. Clare et al. later described the long-term results of this protocol[15]. Type-I malunions, with a large lateral wall exostosis without subtalar arthrosis or hindfoot malalignment, were treated with a lateral wall ostectomy and peroneal tenolysis, without subtalar arthrodesis. Type-II malunions, with a large lateral wall exostosis as well as subtalar arthrosis, were treated with a lateral wall ostectomy, peroneal tenolysis, and subtalar bone-block arthrodesis. Type-III malunions, with a large lateral wall exostosis, subtalar arthrosis, and >10° of hindfoot malalignment, were treated with a lateral wall ostectomy, peroneal tenolysis, subtalar bone-block arthrodesis, and a calcaneal osteotomy. In their series of forty type-II and III malunions, there was an initial fusion rate of 93%; all three nonunions underwent revision arthrodesis and united successfully. Overall, the protocol was effective for relieving pain, reestablishing a stable plantigrade foot, and improving patient function. The authors found it most difficult to restore talocalcaneal height in patients with type-III malunions. Given the difficulty encountered in restoring calcaneal height and the talocalcaneal relationship in this group of patients, the authors concluded that many patients with a displaced intra-articular calcaneal fracture would benefit from initial operative intervention.

Previous studies have compared the results of operative and nonoperative treatment of acute displaced intra-articular calcaneal fractures[10]. Thordarson and Krieger prospectively randomized thirty patients with Sanders type-II and III displaced intra-articular calcaneal fractures to initial nonoperative or operative treatment[8] and found that patients managed with open reduction and internal fixation had higher functional scores seventeen months after surgery. In the retrospective, nonrandomized study by Leung et al., the results for forty-four patients who had been managed operatively were compared with those for nineteen patients who had been managed nonoperatively[28]. The operative treatment group had better results with respect to pain, activity, range of motion, return to work, and swelling of the hindfoot.

Thermann et al. retrospectively examined forty patients who had undergone subtalar arthrodesis for the treatment of posttraumatic subtalar arthritis following a displaced intra-articular calcaneal fracture[20]. Initially, twenty-three fractures

had been treated nonoperatively and seventeen had been treated with open reduction and internal fixation. Subtalar fusion was performed at a mean of 3.5 years after the fracture; the average duration of follow-up after the arthrodesis was 5.2 years. The clinical results were much better for the fractures that initially had been treated with open reduction and internal fixation as compared with those that had required reconstruction of a calcaneal malunion following initial nonoperative treatment. Because of the small sample size, however, the study did not demonstrate a significant difference in long-term outcomes.

Csizy et al. prospectively evaluated forty-four patients who required late subtalar fusion following a displaced intra-articular calcaneal fracture[10]. The degree of the initial injury (including a Bohler angle of ≤0°) was the primary prognostic determinant of long-term patient outcome. Thirty-seven (17%) of the 218 patients with a displaced intra-articular calcaneal fracture that had been treated nonoperatively required a delayed subtalar arthrodesis, compared with <5% of patients who initially had been managed with open reduction and internal fixation. Overall, the data showed that initial nonoperative care was five times more likely to lead to the need for a late fusion as compared with open reduction and internal fixation.

Randle et al., in a meta-analysis of six studies investigating the surgical treatment of calcaneal fractures, reported that patients who were managed nonoperatively were 1.5 times more likely to experience pain[50]. Although there was a trend for operatively managed patients to have better outcomes with respect to pain, return to work, heel width, gait abnormalities, and radiographic outcomes, significance could not be demonstrated because of the small sample sizes. In a prospective, randomized, controlled study, Buckley et al.[9] compared the results of operative and nonoperative treatment of displaced intra-articular calcaneal fractures. The study suggested that anatomic or near-anatomic reduction confers a positive effect on outcome, especially in patients not receiving Workers' Compensation. Nonoperatively managed patients were 5.5 times more likely to require a subtalar arthrodesis. Similarly, the prospective, randomized, multicenter study by Howard et al. demonstrated that patients with displaced intra-articular calcaneal fractures who were managed nonoperatively were more than five times more likely to require a later subtalar arthrodesis[11]. Finally, the recent economic analysis by Brauer et al. demonstrated that initial operative treatment resulted in a lower rate of late subtalar arthrodesis, an improved quality of life, and a more cost-effective form of treatment[51].

The current study presents the results of procedures performed by a single surgeon who has treated >600 acute calcaneal fractures surgically; fewer than 6% of these patients have gone on to require subsequent subtalar fusion. Our analysis was aided by a 100% follow-up rate. The consistent use of a standard surgical protocol is a second strength of the present study. The limitations of the present study include its retrospective nature and the fact that it represents the experience of only one surgeon. Nevertheless, it is our belief that other surgeons specializing in the treatment of displaced intra-articular calcaneal fractures can be expected to have similar outcomes.

The significantly improved Maryland Foot Scores and ankle-hindfoot scores in the patients in Group A support our hypothesis that improved outcomes can be expected following subtalar arthrodesis in patients who undergo initial open reduction and internal fixation after a displaced intra-articular fracture of the calcaneus. It is now clear to us that the restored anatomic shape of the calcaneal body after initial open reduction and internal fixation allows for a simpler in situ subtalar fusion, with fewer complications and improved functional results.

Some authors have advocated limiting the incision to a straight posterior approach when treating a calcaneal malunion[38,40]. If this approach is used, however, it is not possible to address the lateral wall exostosis, the peroneal tendons, or the anterior calcaneocuboid joint[12,15]. When the reconstruction involves using a standard extensile lateral approach and raising a full-thickness subperiosteal flap, all pathologic aspects of the malunion can be addressed. Unfortunately, attempts to restore height can result in tension at the incision line, and this may have contributed to the higher wound complication rate in Group B. Therefore, if the surgeon is concerned about tension at the incision line when correcting a calcaneal malunion, complete correction of calcaneal height may not be advisable. This is yet another limitation associated with initial nonoperative treatment of these fractures.

In conclusion, we believe that the present study supports the hypothesis that open reduction and internal fixation of displaced intra-articular calcaneal fractures leads to improved outcomes when the calcaneus is anatomically reduced. Following an acute injury to the calcaneus, it is important to restore not only articular congruency but also the shape and alignment of the calcaneus. This reduction must be maintained until union is achieved. If posttraumatic arthritis of the subtalar joint develops over time, and if a subtalar arthrodesis is required, the reconstructive procedure will be easier technically, without the problems associated with a malunion, as calcaneal shape and alignment have already been restored. In addition, because calcaneal height is established when open reduction and internal fixation is performed, postoperative wound complications at the time of subtalar fusion surgery will be less frequent. Patients with displaced intra-articular calcaneal fractures that are treated with initial open reduction and internal fixation can be expected to experience better clinical and functional outcomes with greater long-term benefits should they require later subtalar arthrodesis as compared with patients who received initial nonoperative treatment. ■

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Craig S. Radnay, MD, MPH
Insall Scott Kelly Institute, 210 East 64th Street, 4th Floor,
New York, NY 10065

Michael P. Clare, MD
Roy W. Sanders, MD
Orthopaedic Trauma Service, Florida Orthopaedic Institute,
4 Columbia Drive, Suite #710, Tampa, FL 33606.
E-mail address for R.W. Sanders: ots1@aol.com

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