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SYMPOSIUM: TSCHERNE FESTSCHRIFT

Severity of Injury Predicts Subsequent Function in Surgically Treated Displaced Intraarticular Calcaneal Fractures

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Abstract

Background The treatment of displaced, intraarticular calcaneal fractures (DIACFs) remains challenging and the best treatment choices remain controversial. The majority of patients will have some lasting functional restrictions. However, it is unclear which patient- or surgeon-related factors predict long-term function.

Questions/purposes We determined (1) the impact of patient- and surgeon-related factors on function of patients after internal fixation of DIACFs and (2) whether severity of injury correlated with subsequent function.

Methods We retrospectively reviewed all 210 patients operatively treated for 242 DIACFs between 2000 and 2003; of these, 127 patients (60%) with 149 fractures were available for followup at a minimum of 69 months (average, 95 months; range, 69–122 months). Severity of injury was quantified by the classifications of Sanders and Zwipp Function was quantified using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot score, an adjusted Zwipp score, the Foot Function Index (FFI), and the SF-36 physical and mental component summary (PCS and MCS) scores.

Results At latest followup, the median AOFAS score was 77, the median Zwipp score was 60, the median FFI was 27, and the median SF-36 PCS and MCS scores were 44 and 55, respectively. The foot-related scores and the SF-36 PCS negatively correlated with the severity of injury, work-related injuries, and bilateral fractures.

Conclusions We found the severity of a DIACF related to subsequent foot function and quality of life. Both fracture severity classifications predicted function. Anatomic reconstruction of the shape and articular surfaces of the calcaneus leads to predictable function in the medium to long term.

Level of Evidence Level IV, prognostic study. See Instructions for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

The ideal choice of treatment for displaced, intraarticular calcaneal fractures (DIACFs) continues to generate controversy [52]. Residual deformity and/or incongruity in the posterior facet of the subtalar joint after DIACFs are associated with restriction of global foot function [12, 24, 45, 52, 54, 65] and reportedly lead to painful subtalar arthritis for which subtalar fusion is performed [9, 14, 24, 48, 61].

French surgeons, most notably Leriche, pioneered open reduction and internal fixation of DIACFs with plates and staples in the early 1920s [33]. Lenormant et al. [32] proposed grafting of the subthalamic impaction zone after lifting the depressed joint fragment, a method later popularized widely by Palmer [44]. Because of the complications associated with open approaches and the lack of adequate fixation methods, nonoperative and minimally invasive techniques dominated the treatment of calcaneal fractures until the late 1970s when Belgian, French, and Italian surgeons reported between 77% and 80% "good" to "excellent" functional scores in large series on newly developed open approaches and fixation methods [4, 30, 34].

Since the 1980s, a large number of clinical studies have described the operative treatment of DIACFs [2, 5, 7, 9, 17, 21–23, 25, 26, 29, 36–39, 42–45, 47–50, 55, 57, 59, 63, 67, 68]. However, comparison of these studies is difficult because of diverse treatment protocols and outcome measurements. For the same reason, two meta-analyses [27, 53] reporting totals of 242 to 891 patients at 1 to 15 years' mean followup from comparative studies failed to produce a clear recommendation in the treatment of these injuries, although operative treatment with anatomic reconstruction was slightly favored in both. Furthermore, function seems to be influenced by many patient-related factors such as employment and insurance status—above all, workers compensation—that may confound the data in the available studies [9, 17].

Under the auspices of Professor Harald Tscherne, the senior author (HZ) developed several techniques for open reduction and internal fixation of DIACFs in the mid-1980s [69]. In 1993, Zwipp et al. [68] reported on 123 patients at an average followup of 3 years. Function and radiographic findings as reflected in a 200-point score [65] were substantially better than in a historic group treated nonoperatively at the same center. A subsequent series from our group with 168 patients followed for an average of 18 months [50] revealed several prognostic factors (closed versus open fractures, congruent posterior facet of the subtalar joint, correction of Böhler's tuberosity joint angle within 30% of the uninjured side) that positively influenced function (Zwipp score [65], American Orthopaedic Foot and Ankle Society [AOFAS] Ankle-Hindfoot score [28]). Other authors [2, 5, 55] with mean followups ranging from 18 to 25 months have reported similar prognostic factors. Few studies [26, 37, 38, 47] have reported followup of more than 5 years after operative treatment. Two include larger patient cohorts (47 to 81 patients) and report function at 10 to 12 years after operative treatment of DIACFs [37, 47]. These studies found patients in motor vehicle accidents had worse function [47] and restoration of Böhler's angle positively affects function as measured with the AOFAS score [37]. However, it is unclear whether or how other factors such as age, workers compensation, fracture severity, and the presence of step-offs in the subtalar joint, influence long-term function measured with validated scores.

We therefore determined (1) postoperative complications and the rate of revisions after internal fixation of DIACFs, (2) the necessity of secondary subtalar arthrodesis, (3) function beyond 5 years, and (4) the influence of several patient- and surgery-related factors on function.

Patients and Methods

We retrospectively reviewed prospectively collected data on all 210 patients with 242 DIACFs treated operatively between January 1, 2000, and December 31, 2003. All patients were entered into a database containing the following information: patient demographics, occupational status, pathomechanism of the accident, fracture classification according to Sanders [54] and Zwipp [65], soft tissue damage according to Gustilo and Anderson [18] and Tscherne and Oestern [62], additional injuries, comorbidities, surgical treatment, and early rehabilitation. During the study time, we treated 235 patients with 273 displaced intraarticular calcaneal fractures. Indications for surgery were intraarticular fractures with a step-off of 2 mm or more [50]. Contraindications to surgery were (1) poorly controlled diabetes mellitus, (2) advanced arterial disease or venous insufficiency, (3) manifest immune deficiency, (4) patients we judged might be noncompliant, (5) extra-articular and nondisplaced intraarticular fractures (Sanders Type I), (6) children younger than 14 years, (7) patients who were not able to consent, (8) paraplegic patients, and (9) patients with pathologic fractures of the calcaneus. This left 210 patients who were treated operatively. All were contacted by mail between June 2009 and September 2010 to take part in the followup study. One hundred seventeen patients (56%) presented for followup appointments. Eleven patients (5.2%) had died by the time of followup, 32 (15%) had moved to an unknown location and could not be contacted despite extensive search, and 50 (24%) declined to present for followup because they had moved to a distant location or were living abroad. The latter group was asked to participate by mail. Ten patients from this group responded by filling out and sending back the questionnaires. Thus, followup could be obtained from 127 of 199 living patients (64%). Of the 127 patients available for followup, 22 had bilateral intraarticular calcaneal fractures; therefore, 149 fractures were reexamined. Seventy-one fractures affected the right foot, and 78 fractures the left foot. The mean age of the 23 (18%) women and 104 (82%) men was 43.1 years (range, 14–76 years) at the time of the accident. Relevant comorbidities included hypertension (n = 30), diabetes mellitus (n = 5), osteoporosis (n = 5), and other secondary disorders (n = 36), eg, asthma and allergies. Sixty-nine patients (54%) had no comorbidity. The minimum followup was 69 months (average, 95 months; range, 69–122 months).

Almost ⅔ (64%) of the accidents (n = 81) occurred during leisure time and ⅓ of the accidents (n = 46) were industrial injuries. Ninety-nine injuries (78%) were produced by a fall from a mean height of 3.0 m (range, 0.4–30 m; median, 2.0 m), most often a fall from a ladder (n = 45), followed by horizontal crush injuries (n = 19, 15%) from vehicle, horse, or motorsport accidents. Fourteen injuries (19%) occurred after minor trauma, such as stumbling across furniture. Using the classification of Sanders [54], there were 47 Type II, 54 Type III, and 48 Type IV fractures. According to the 12-point fracture severity scale of Zwipp et al. [68], 21 fractures scored 3 to 6 points, 74 fractures scored 7 to 9 points, and 54 fractures scored 10 to 12 points, the latter representing high-energy (blowout) fractures. There were eight open fractures, two Gustilo-Anderson Type I, four Type II, and two Type III [18]. Among the 141 closed fractures, 12 were graded Tscherne 0, 70 Tscherne 1, 53 Tscherne 2, and six Tscherne 3 [62].

Surgery was performed at an average of 10.2 days (range, 0–31 days) from the time of injury by eight different surgeons experienced in foot and ankle trauma. The majority of fractures (n = 113, 76%) were reduced via an extended lateral approach and lateral plate fixation; in three feet (2.0%), bilateral approaches were used. Fourteen Sanders Type II fractures, three Sanders Type III fractures, and three Sanders Type IV fractures were treated with percutaneous screw fixation. In Sanders Type IIA and IIB fractures, this was performed in combination with arthroscopic control of subtalar joint reduction, as described in detail recently [49, 51]. In the remainder of fractures, open reduction of displaced fractures at the sustentaculum and anteromedial facet of the subtalar joint was performed via a modified medial (sustentacular) approach [65, 67] and a combination of screw and K-wire fixation.

For lateral plate fixation, the patient was placed on a radiolucent operating table in a lateral decubitus position on the noninjured side. The skin incision was carried out L-shaped over the lateral aspect of the heel running at ⅔ of a line between the lateral malleolus and the posterior and inferior border of the heel respectively [2, 54, 67], thus respecting the course of the lateral calcaneal artery and the sural nerve. A full-thickness fasciocutaneous flap was raised, including the peroneal tendons raised from the peroneal tubercle and mobilized within their sheath. Mobilization and finally reduction of the tuberosity fragment were achieved with a 6.5-mm Schanz screw introduced axially via a posterior stab incision [68]. The fractured posterior facet was reduced in a stepwise fashion from medial to lateral. In three cases of comminuted fractures of the sustentaculum tali, a separate small approach directly over the sustentaculum was used, with the patient placed supine, the leg prepared mobile, and a pad placed under the hip [67]. With percutaneous leverage, downward displacement of the tuberosity and varus or valgus malalignment were corrected. Then, the reconstructed posterior facet as a whole was brought into alignment with the tuberosity and the anterior process fragments and fixed temporarily with K-wires (Fig. 1).

Assessment of the reduction was achieved with two- or three-dimensional fluoroscopic imaging and open subtalar arthroscopy to directly assess the quality of joint reduction [51]. If residual step-offs were seen, the K-wires were removed temporarily and joint reduction was repeated (Fig. 2). Internal fixation was completed with the use of an anatomically shaped plate affixed to the restored lateral calcaneal wall in 119 feet (80%) and with screws in 30 feet (20%). The nonlocking AO (Tampa) calcaneal plate [55] and the locking AO plate [67] (both by Synthes, Bettlach, Switzerland) were used in 68 and 61 feet, respectively (Fig. 3). Screws were placed into the tuberosity, the thalamic portion, and the anterior process according to the individual fracture pattern. To achieve compression of the plate to the lateral wall, the first one or two screws were inserted in a conventional, nonlocking mode.

The postoperative protocol included active and passive ROM exercises in the ankle, subtalar, and Chopart joints and isotonic and isometric exercises of the leg beginning at the second postoperative day. This was accompanied by use of a continuous passive motion device for the ankle and subtalar joints for 2–4 hours daily. A splint was applied until the wound healed. Patients were then restricted to partial weightbearing (approximately 20 kg) in their own shoes for 6 to 12 weeks, depending on the severity of the fracture.

Physical examination was performed for 117 of the 210 patients (55%) at our institution by one of the authors (CD) not involved in the operative treatment of the patients. These findings (Fig. 4) were also used for the completion of the AOFAS score [28] and Zwipp score [65]. Questionnaires were filled out by the 127 patients and included the validated German versions [41] of the Foot Function Index (FFI) [10] and the SF-36 physical and mental component summary (PCS and MCS) scores [63]. The collected data were compared to the all-German normative population sample from 1994 (n = 2914) [11], matched by sex and age to the equivalent mean of the sample. The Zwipp score was adjusted from ±200 to ±130 for all patients to make the findings comparable with those from patients who did not have a full set of radiographs at the time of followup.

Two of us (CD, SR who was among the treating surgeons) assessed Böhler's angle and fracture union on lateral and

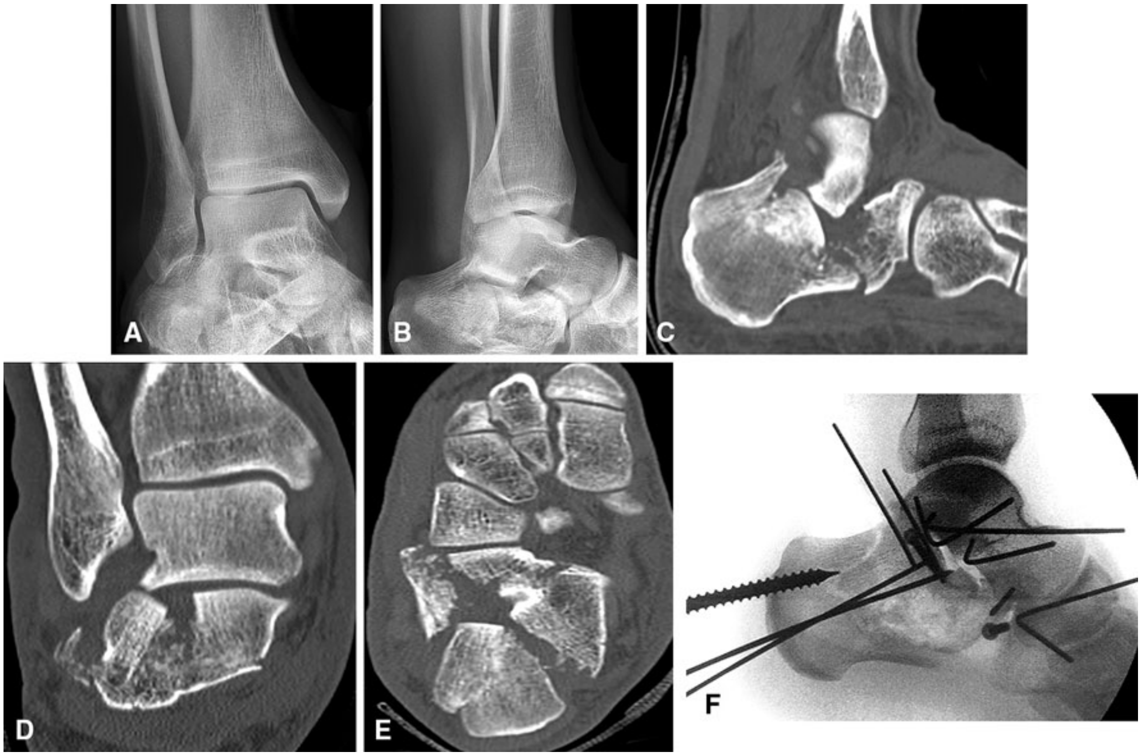

Fig. 1A–F (**A**) AP and (**B**) lateral radiographs of a 41-year-old patient show a displaced fracture of the calcaneus. (**C**) Sagittal, (**D**) coronal, and (**E**) horizontal CT scans display the amount of displacement, involvement of the subtalar and calcaneocuboid joints, and number and size of major fragments. (**F**) Open reduction and internal fixation started with reconstruction of the posterior facet of the subtalar joint and calcaneocuboid joint and restoration of the overall shape of the calcaneus followed by K-wire transfixation.

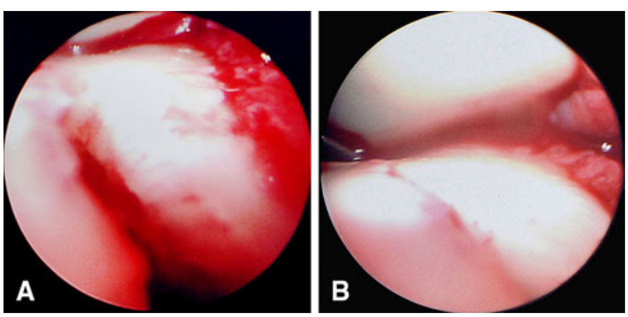

Fig. 2A–B In the same patient as in Fig. 1, (**A**) open arthroscopic control of the joint reduction revealed a residual incongruity of the joint surface secondary to a tilted lateral fragment. (**B**) After repeat reduction, the joint surface appears even.

axial weightbearing radiographs (Fig. 5). Union was defined as trabecular continuity across the former fracture. Böhler's angle (ie, the tuberosity-joint angle [65]) was measured on the lateral radiographs of the injured foot pre- and postoperatively at the time of followup and of the uninjured foot. An interobserver correlation coefficient of 0.72 has been reported for measuring Böhler's angle [64]. The presence of postoperative step-offs in the posterior facet of the subtalar joint was assessed in Brodén's views [65] or postoperative CT scans (Fig. 6), if available. Step-offs of 1 mm and more were recorded since this dimension can reliably be measured with both types of images [5, 25, 50]. In our series, the presence and size of step-offs in the posterior facet could be reliably evaluated with the available radiographs and postoperative CT scans in 120 of the 149 feet (81%). Eighty-five patients (71%) had no discernible step-off in the posterior facet or an incongruity of less than 1 mm. Twenty-two (18%) had a step-off between 1 mm and less than 2 mm, and 11 patients (9%) had a step-off of more than 2 mm.

We examined the influence of six patient-related factors (industrial versus leisure accident, open versus closed soft tissue injury, unilateral versus bilateral fractures, age, fracture severity as reflected by the classifications of Zwipp [65] and Sanders [54]) and three surgery-related factors (time to surgery more versus less than 14 days, reduction of Böhler's angle, quality of joint reduction) on these functional scores. The function scores (AOFAS, FFI, adjusted Zwipp, SF-36) were set as dependent variables for each set of independent variables. The data were evaluated using multivariate linear regression analysis. Of the bilateral fractures, only one side was randomly selected for inclusion into the linear regression analysis that was therefore performed on 138 fractures. Data were evaluated using SPSS® 19.0 (SPSS Inc, Chicago, IL, USA). Graphics were created with Mathematica® 8 (Wolfram Research, Champaign, IL, USA).

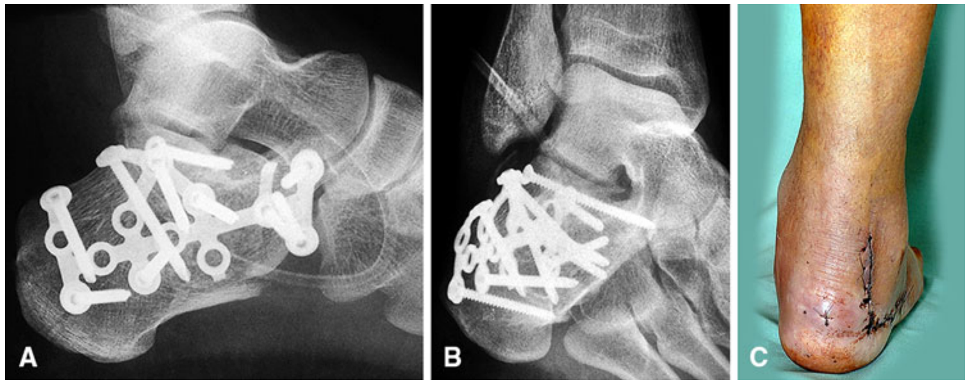

Fig. 3A–C In the same patient as in Fig. 1, (**A**) lateral and (**B**) Brodén projections show anatomic restoration of the joint surfaces and the overall shape of the calcaneus after plate fixation. (**C**) The scar of the extensile lateral approach looks uneventful 7 days after surgery.

Fig. 4A–B In the same patient as in Fig. 1, (**A**) at 7 years' followup, the hindfoot is well aligned and the foot is plantigrade. (**B**) Inversion and eversion of the hindfoot are restricted while plantarflexion and dorsiflexion are unrestricted when compared to the uninjured side.

Results

No early loss of reduction or implant failure occurred. Union rate was 100%. Postoperatively, a superficial wound edge necrosis developed in 22 feet (15%) that healed without further intervention. A postoperative hematoma required revision in four feet (2.7%) and a deep soft tissue infection in eight feet (5.4%). The lateral plate was removed and replaced by screws in three feet. A local flap was needed in four feet for soft tissue coverage after

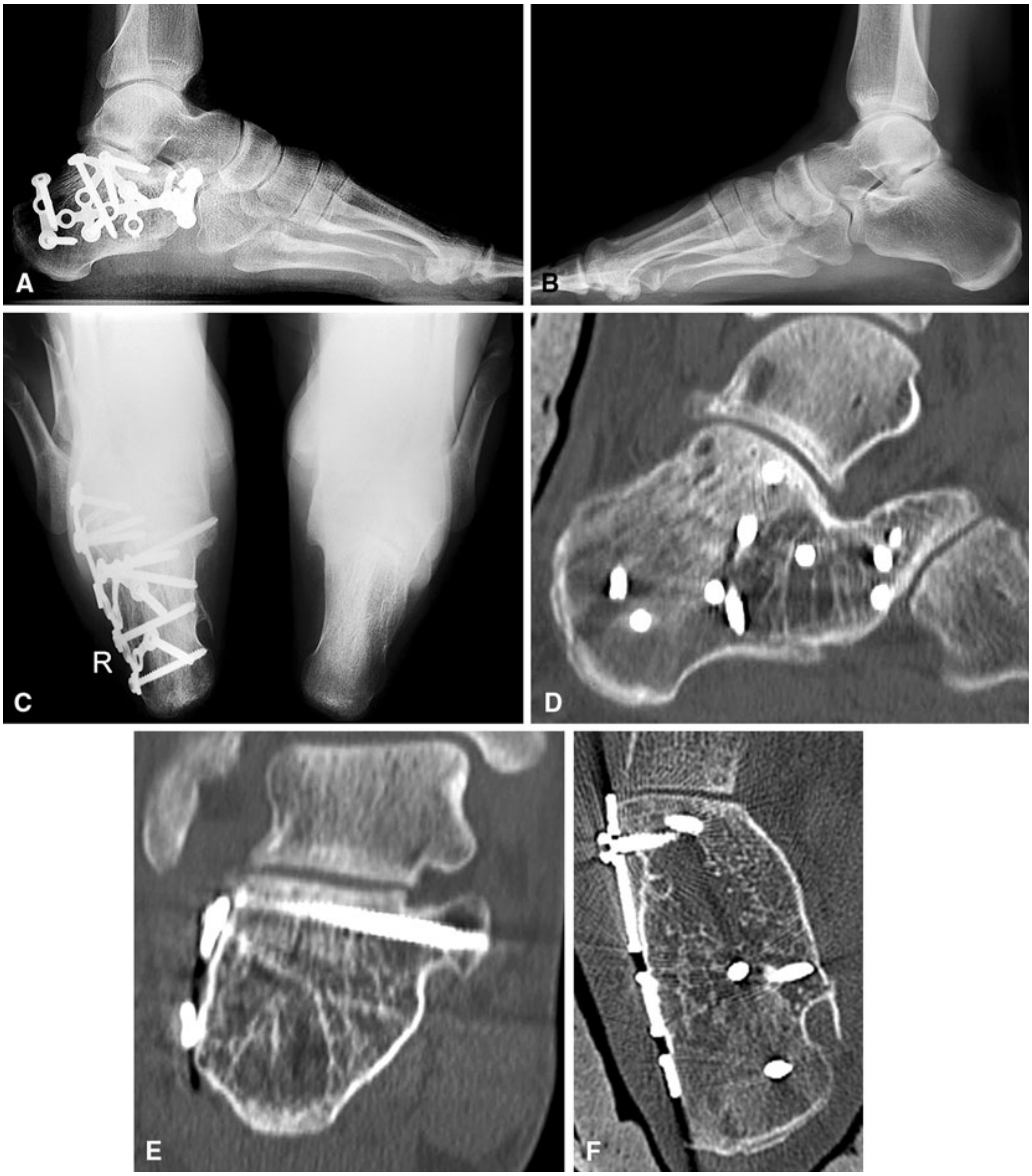

Fig. 5A–F In the same patient as in Fig. 1, lateral standing radiographs at 7 years followup do not show any difference in the axial alignment between (**A**) the formerly injured foot and (**B**) the uninjured foot. (**C**) The axial standing radiograph demonstrates equal calcaneal width and axial alignment in the frontal plane. (**D**) Sagittal, (**E**) coronal, and (**F**) horizontal CT scans show anatomic reconstruction of the subtalar and calcaneocuboid joints without signs of subtalar arthritis.

adequate débridement. No chronic osteomyelitis was observed during the followup period. At the time of followup, about ⅔ of the patients (n = 85) had the implants removed. In 29 patients (20%), implant removal had been combined with an extra- and intraarticular débridement and open arthrolysis of the subtalar joint [51].

A subtalar arthrodesis was performed in nine feet (6%) for painful posttraumatic arthritis. Four of these initially had Sanders Type II, one had Type III, and four had Type IV fractures.

At the time of followup, the median AOFAS score was 77.0, the median adjusted Zwipp score was 60.0, and the median FFI was 26.7 (Table 1). The median SF-36 PCS score was 44.5 (which was lower than the mean German population norm of 49.1 [11]), and the median SF-36 MCS score was 54.6 (slightly higher than the German population norm of 51.5). Twenty-one patients (17%) took some amount pain medication and 24 (19%) had insoles.

We found a correlation between the injury severity (12-point score of Zwipp) (Fig. 6) and the AOFAS score ($p < 0.001$), the adjusted Zwipp score ($p < 0.001$), and the FFI ($p = 0.009$). Similarly, patients with Sanders Type III and IV fractures had lower FFI ($p = 0.047$) and SF-36 MCS scores ($p = 0.040$) than those with Type II fractures.

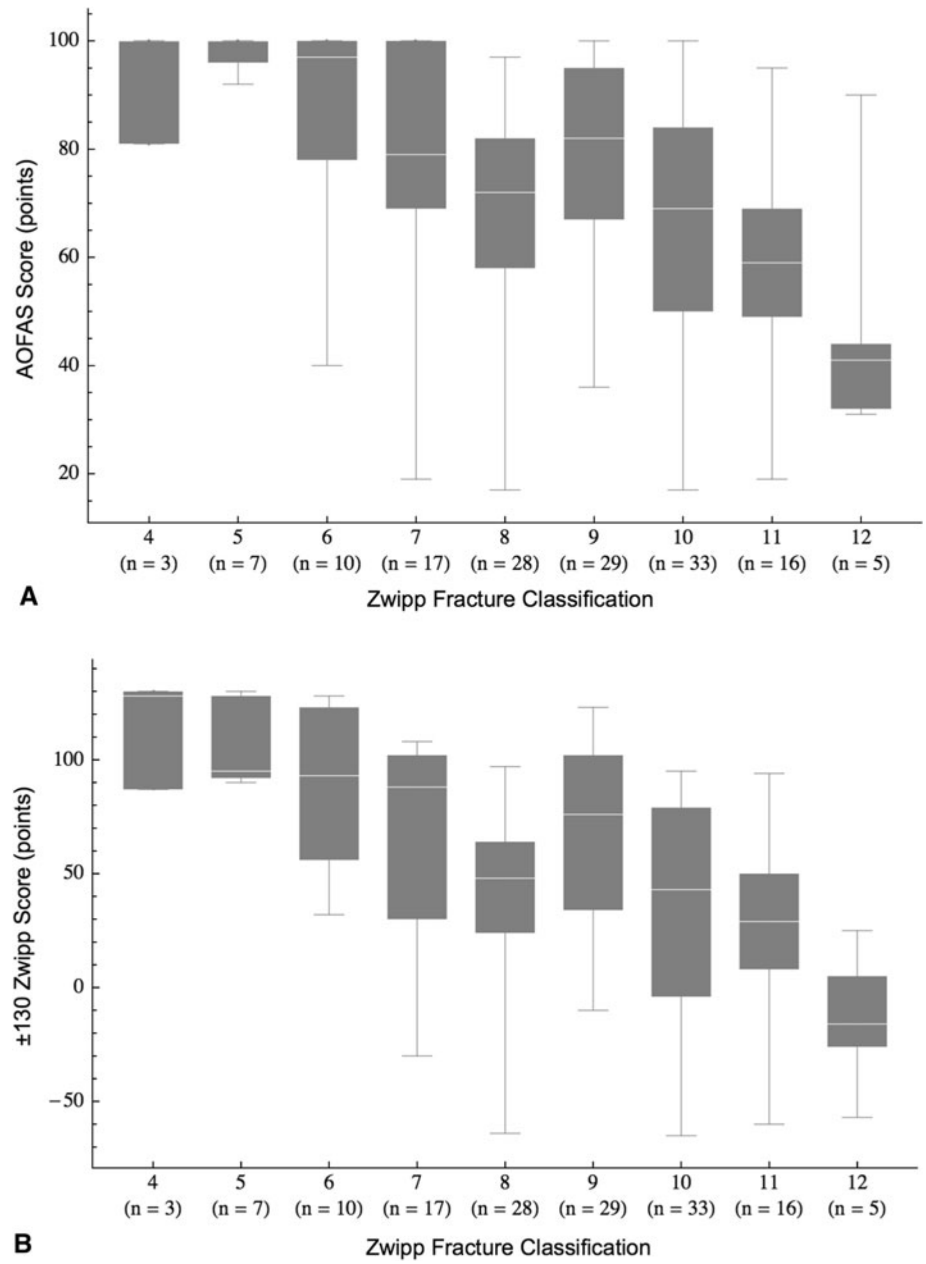

Fig. 6A–B Graphs shows a correlation between the injury severity as expressed by the Zwipp fracture score and the outcomes measured with (**A**) the AOFAS score ($p < 0.001$) and (**B**) the adjusted Zwipp score ($p < 0.001$). Horizontal line = median; box = 25th to 75th percentile; whiskers = minimum and maximum values.

We further found a correlation between the injury severity scores of Zwipp and Sanders. Patients with open fractures had lower adjusted Zwipp scores ($p = 0.042$) than those with closed fractures. Patients with bilateral fractures had lower AOFAS scores ($p = 0.033$) and SF-36 MCS scores ($p = 0.051$) than those with unilateral fractures. Patients who had suffered industrial injuries and were eligible for workers compensation had lower FFI ($p = 0.013$) and SF-36 PCS scores ($p = 0.051$) than patients with leisure accidents. We identified no correlation between patient age and all scores (Fig. 7). The AOFAS scores, adjusted Zwipp scores, and FFI tended to be lower ($p = 0.246$ to 0.289) with increasing step-offs in the posterior facet (Fig. 8) and tended to be lower ($p = 0.084$ to 0.234) with lower postoperative Böhler's angles (Fig. 9).

Discussion

The treatment of DIACFs remains a surgical challenge. The few available long-term studies on open reduction and internal fixation [26, 37, 38, 47] report on between 16 and 81 patients and identified several positive prognostic factors, such as joint congruity, restoration of Böhler's angle, heel width, age less than 50 years, low body weight, and light workload, which were not consistent throughout the studies. We therefore examined (1) postoperative complications and the rate of revisions after internal fixation of DIACFs, (2) the necessity of secondary subtalar arthrodesis, (3) function beyond 5 years, and (4) the influence of several patient- and surgery-related factors on function.

Table 1. Summary of the functional outcome scores as dependent variables and several prognostic factors as independent variables

Independent variable	Dependent variable*				
	AOFAS Ankle-Hindfoot score (0–100 points)	Adjusted Zwipp score (−130 to +130 points)	FFI (0–100 points, 0 at best)	SF-36 PCS score (0–100 points)	SF-36 MCS score (0–100 points)
Overall (n = 149 fractures)	72.6 ± 22.7	53.3 ± 48.7	29.5 ± 24.4	43.8 ± 11.3 [49.1 ± 9.4]†	52.8 ± 8.8 [51.5 ± 7.8]†
Type of accident					
Industrial accident (n = 46)	65.9 ± 19.6	38.1 ± 44.0	37.4 ± 22.4	39.6 ± 10.9	54.6 ± 9.3
Leisure accidents (n = 81)	79 ± 21.0	67.0 ± 45.4	21.6 ± 22.6	47.0 ± 10.6	52.4 ± 8.1
p value	0.133	0.173	0.013	0.051	0.320
Soft tissue injury					
Open (n = 8)	52.4 ± 19.5	0.25 ± 43.2	41.3 ± 18.9	37.5 ± 10.3	51.1 ± 11.9
Gustilo-Anderson: O1 (n = 2), O2 (n = 4), O3 (n = 2)					
Closed (n = 141)	73.7 ± 22.4	56.3 ± 47.3	28.9 ± 24.5	44.2 ± 11.3	52.9 ± 8.7
Tscherne: G0 (n = 12), G1 (n = 70), G2 (n = 53), G3 (n = 6)					
p value	0.102	0.042	0.502	0.100	0.171
Injury pattern					
Solitary unilateral (n = 65; 44%)	77.4 ± 18.2	63.4 ± 43.0	24.5 ± 22.8	45.6 ± 11.3	54.6 ± 7.7
Solitary bilateral (n = 38; 26%)	62.2 ± 25.4	34.7 ± 52.9	41.5 ± 25.0	41.0 ± 12.3	52.5 ± 9.0
p value	0.033	0.229	0.122	0.107	0.051
Zwipp classification					
1 joint, 1–3 fragments (n = 21)	92.1 ± 14.6	101.1 ± 28.4	12.5 ± 23.6	48.1 ± 10.8	52.3 ± 10.2
2 joints, 4–5 fragments (n = 58)	70.3 ± 24.3	49.1 ± 47.5	33.8 ± 25.5	42.5 ± 11.5	52.6 ± 9.3
3 joints, 5 fragments (n = 70)	68.6 ± 20.5	42.5 ± 46.5	31.1 ± 21.7	43.6 ± 11.2	53.2 ± 8.2
p value	< 0.001	< 0.001	0.009	0.120	0.071
Sanders classification					
II (n = 47)	76.7 ± 25.3	67.2 ± 47.8	28.25 ± 28.19	43.3 ± 12.5	54.6 ± 8.3
III (n = 54)	75.8 ± 19.9	58.8 ± 41.3	26.02 ± 21.91	45.4 ± 11.1	53.0 ± 7.1
IV (n = 48)	64.9 ± 21.4	33.5 ± 51.6	34.72 ± 22.56	42.6 ± 10.5	50.8 ± 10.8
p value (II vs III–IV)	0.475	0.435	0.047	0.740	0.040

* Values are expressed as mean ± SD; †values from an all-German normative population sample from 1994 (n = 2914) [11]; AOFAS = American Orthopaedic Foot and Ankle Society; FFI = Foot Function Index; PCS = physical component summary; MCS = mental component summary.

Our study has several limitations. First, we had no control group and cannot say whether our treatment approach is superior to that of others. Second, more than ⅓ of the patients were lost to followup. Because we are a referral center for calcaneal fractures, many patients came from distant locations. Others had moved to an unknown location. However, compared to the available literature, our study represents one of the largest patient cohorts followed for more than 5 years with a wide array of clinical, patient-reported, and radiographic measurements. Third, we used the AOFAS score [28] as one of the outcome measures. Recently, the use of this score has been discouraged by the AOFAS itself as it is reportedly neither reliable nor valid [46]. At the time of planning the study, it was the most frequently used score for hindfoot disorders [31], thus allowing some comparison of our findings with those of other studies. Fourth, despite the relatively large cohort, we were still limited in the number of potentially confounding variables we could examine.

Despite meticulous handling of the soft tissues, a superficial wound edge necrosis was noted postoperatively

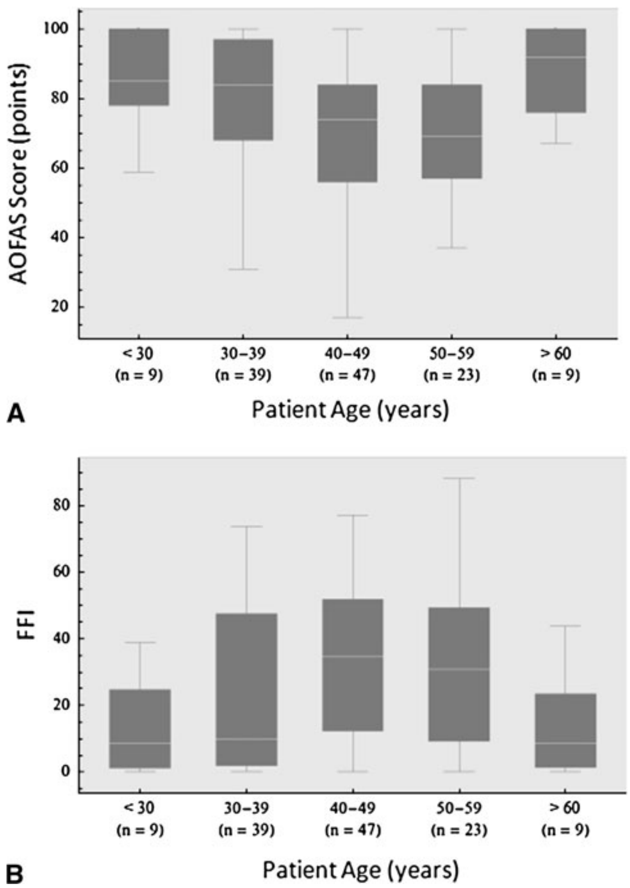

Fig. 7A–B Graphs show (**A**) the AOFAS score (p = 0.911) and (**B**) FFI (p = 0.884) in their relation to increasing patient age. Horizontal line = median; box = 25th to 75th percentile; whiskers = minimum and maximum values.

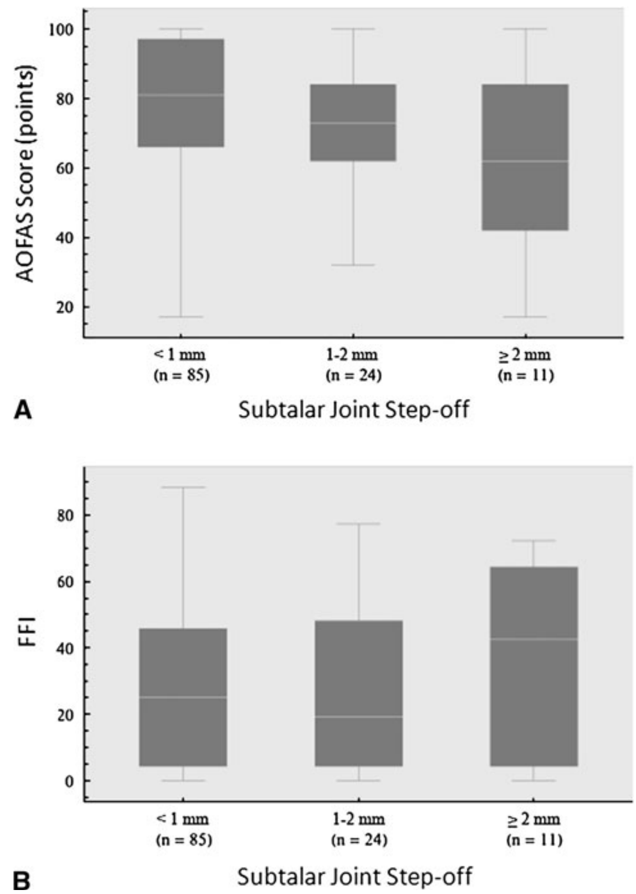

Fig. 8A–B Graphs show a tendency toward inferior outcomes in (**A**) AOFAS score (p = 0.240) and (**B**) the FFI (p = 0.243) with increasing step-offs in the posterior facet. Horizontal line = median; box = 25th to 75th percentile; whiskers = minimum and maximum values.

in 15%. This is consistent with other studies that found between 2% and 20% of wound edge necrosis when using an extended lateral approach [1–3, 13, 15, 20, 50, 68] and up to 27% with bilateral approaches [59]. All wounds healed with local care. A postoperative hematoma requiring revision was seen in 2.7% and a deep soft tissue infection in 5.4%. In comparable studies, deep infections developed in 0% to 7% of closed fractures [2, 3, 20, 26, 58, 68]. With early revision and proper débridement, progression to osteomyelitis requiring partial calcanectomy or even below-knee amputation could be avoided in the present series. To prevent infection, we aim at early soft tissue coverage in cases of complex injuries with Gustilo-Anderson Type III open fractures [8].

Development of posttraumatic subtalar arthritis is a recognized consequence of DIACFs. In our study, the rate of late subtalar arthrodesis was 6%, which is in keeping with the reported rates of between 0% and 15% [7, 9, 50, 55, 58, 69]. Csizy et al. [14] identified several factors that predict the need for a late subtalar arthrodesis: patients with a work-related injury, Sanders Type IV fractures, initial Böhler's angle of less than 0°, and initial nonoperative treatment. Sanders et al. [55], in their series of 120 patients, noted also 14 patients with anatomic reduction required a secondary subtalar fusion. They speculated cartilage necrosis might be the reason for posttraumatic joint degeneration despite anatomic reduction, which is supported by a histologic study [6] showing chondrocyte death in biopsies taken from avulsed cartilage fragments. We attempt at anatomic reduction in most cases except those with massive primary cartilage loss. If subtalar fusion becomes necessary later, it is technically easier and associated with better function after primary reduction as compared to a corrective fusion for calcaneal malunion [48, 61, 65, 66].

The average AOFAS score of 72.6 found in our study lies in the range from 65 to 82 that has been reported in previous studies (Table 2). The German version of the FFI [10] is reportedly reliable and valid for patients with foot

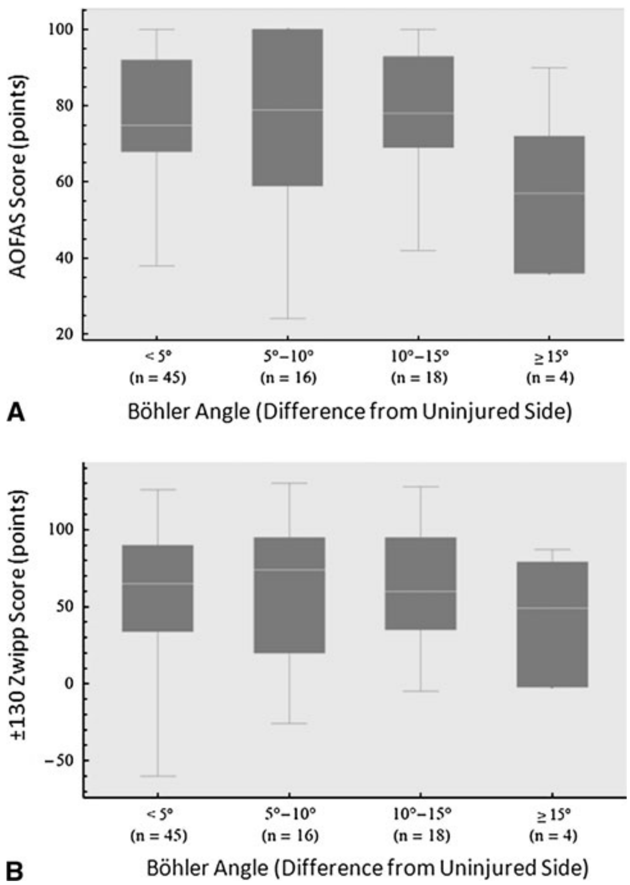

Fig. 9A–B Graphs show a tendency toward inferior results in (**A**) the AOFAS score (p = 0.084) and (**B**) the adjusted Zwipp score (p = 0.104) with greater difference in the postoperative Böhler angle as compared to the uninjured side. Horizontal line = median; box = 25th to 75th percentile; whiskers = minimum and maximum values.

disorders [41]. The average score of 29.5 obtained in our series indicates an overall good result, with 0 being the best and 100 being the worst rating, and is comparable to that of Potter and Nunley [47], who found a score of 20.5 in 81 patients followed for an average of 13 years. The SF-36 [60] is the most utilized score for assessing health-related quality of life [31]. In our study, the average SF-36 PCS score was lower and the average MCS score was slightly higher than that of the German population norms [11]. These findings are similar to those of two recent studies from Germany [23, 63].

The injury severity classifications of Zwipp and Sanders negatively correlated with functional scores, confirming the prognostic value shown in previous studies [5, 39, 50, 55, 65]. Furthermore, bilateral and open fractures yielded inferior function to those of unilateral and closed fractures. These findings indicate a certain amount of late functional limitation is determined at the time of injury. Anatomic reduction of the subtalar joint is an important prognostic factor, although it cannot completely prevent posttraumatic arthritis. A multitude of clinical series report inferior function with residual step-offs of 2 mm or more in the posterior facet [5, 7, 9, 17, 25, 26, 29, 36, 43, 45, 50, 57]. This may be explained by the considerable pressure shift that results from an intra-articular step-off [40, 56]. In contrast to our previous study [50], we only found a weak association between a residual step-off and inferior scores. This is probably due to the fact that only 11 patients (9%) had a step-off of 2 mm and more compared to 23% in our previous study [50], reflecting the growing experience in the treatment of these injuries. A power analysis (bootstrapping approach for Kruskal-Wallis test with a given power of 80% and a significance level of 5%) revealed lower AOFAS and FFI scores would have resulted if 60 patients or more had a step-off of 2 mm or more with the same data distribution. Several authors [7, 26, 37, 39, 43, 50] have found a high postoperative Böhler's angle correlates with higher functional scores. Restoration of Böhler's angle is a good indicator for the quality of reduction of the overall shape of the calcaneus [2, 54, 67]. In our previous short-term study, we found inferior AOFAS and Zwipp scores if Böhler's angle was less than 30% of the unaffected side [50]. In the present study, the number of patients with a low Böhler's angle was too low to show differences. The fact that patients receiving workers compensation have lower functional scores after a variety of injuries is well established [19]. In our study, patients with industrial injuries (36%) had inferior FFI than patients with leisure accidents (64%). Buckley et al. [9] and Geel and Flemister [17] found patients who were receiving workers compensation or had a high workload had a worse result at a mean followup of 3 to 5 years. Potter and Nunley [47] could not replicate these findings in their long-term study, presumably due to a small number (n = 12) in this subgroup of patients. We found no correlation between functional scores and patient age, which is in accordance with recent studies [16, 22]. In our practice, a high patient age is no contraindication to surgery [52].

Based on our data and the literature, anatomic reduction of the joint surfaces and the anatomic shape of the calcaneus and internal fixation for DIACFs led to predictable function in the medium to long term. Functional restrictions remained in a great number of patients but did not necessarily lead to a secondary fusion. Lower functional scores were seen with open and bilateral calcaneal fractures and work-related injuries. Our data confirmed the prognostic value of the fracture severity scores of Zwipp and Sanders with respect to functional scores. The majority of wound-healing problems resolved with local wound care. Infections needed an early débridement to avoid more serious consequences.

Table 2. Complications, functional scores, and prognostic factors reported by previous studies of open reduction and internal fixation with lateral plates and screws for displaced intraarticular calcaneal fractures with a minimum followup of 1 year

Study	Number of patients	Mean followup (years)	Wound edge necrosis (%)	Infection (%)	Subtalar fusion (%)	Results (points)*	Score	Positive prognostic factors
Bèzes [3]	205	3.3	10	2.4	2.7	85% "good/ excellent"	4 functional categories (descriptive)	
Letournel [35]	99	> 2	NR	NR	NR	56% "good/ excellent"	4 functional categories (descriptive)	Reduction of overall shape
Zwipp et al. [67]	123	3	8.3	1.9	3.3	61% "good/ excellent"	Zwipp	Low Zwipp type, surgeon experience
Sanders et al. [55]	120	2.4	4.1	4.1	14.2	73% "good/ excellent"	Maryland Foot Score	Low Sanders type. anatomic joint reduction, surgeon experience
Benirschke and Sangeorzan [2]	80	1.5	10	6	3.8	30% "significant activity modification"		Less severe ST joint injury
Mittlmeier et al. [39]	45	1.9	NR	NR	NR	69% "good/ excellent"	Merle d'Aubigné	Böhler angle, calcaneal width within 20% of other side, ST + CC arthritis, 2-part fracture
Paley and Hall [43][†]	52	9	2	0	2	61% "good/ excellent"	Olerud-Molander	Joint congruity, Böhler angle, heel width, OA, age < 50 years, low body weight, light workload
Brattebø et al. [7]	48	5.6	14.6	6.2	14.6	85/100	Brattebø et al.	Joint reduction within 2 mm, Böhler angle, ST motion
Melcher et al. [38]	16	10.7	6.2	0	0	307/448	Melcher et al.	
Boack et al. [5]	71	2.1	8	3	2.8	66% "good/ excellent"	Zwipp	Joint reduction within 2 mm, low on 12-point fracture scale, low Sanders type
Tennent et al. [61]	51	3.7	19.6	1.9	5.9	81/100	Kerr	Unilateral fractures
Naovaratanophas and Thepchatri [42]	114	6.8	13.3	2.6	NR	84/100	Creigton-Nebraska	Tongue-type
Geel and Flemister [17]	33	4.3	3	0	3	75/100	Thordarson	Anatomic fracture reduction, non-Workers compensation
Buckley et al. [9]	206	3	16	4.8	3.4	69	SF-36	Women, younger men (< 50 years), non-Workers compensation, high Böhler angle, light workload
Rammelt et al. [50]	168	1.5	7.8	6.1	5.8	81/100	AOFAS	Joint reduction within 2 mm, Böhler angle within 30% of the uninjured side, closed fractures
						146/200	Zwipp	
						15/18	Merle d'Aubigné	
Westphal et al. [63]	55	2.9	NR	NR	NR	38	SF-36 PCS	
						50	SF-36 MCS	

Table 2. continued

Study	Number of patients	Mean followup (years)	Wound edge necrosis (%)	Infection (%)	Subtalar fusion (%)	Results (points)*	Score	Positive prognostic factors
Kurozumi et al. [29]	67	1.6	0 (but 37% lateral discomfort)	0	NR	2 (0–9 with 0 being the best score)	Laasonen	Lower age, high Böhler angle, low Sanders type, joint reduction, CC joint reduction
Jardé [26]	27	9.7	7.4	7.4	3.7	42% "good/ excellent"	AOFAS	Reduction of Böhler angle, joint reduction
Herscovici et al. [22]	44	3.7	14	8	6.8	82	AOFAS	
						53	SF-36	
						20	SMFA	
Potter and Nunley [47]	81	12.8	NR	3.7 (revision)	2.5	65/100	AOFAS	Motor vehicle accidents
						21	FFI	
Makki et al. [37]	47	10	10.6	0	10.6	87/100 (ST fusions excluded)	AOFAS	Böhler angle
						81/100	Kerr	
Hirschmüller et al. [23]	60	> 1	16.6	10.0	3.3	65	AOFAS	Low Sanders type (weak), gait velocity, no plantar flexion weakness
						42	SF-36 PCS	
						52	SF-36 MCS	
Current study	168	7.9	14.7	2.8	6.0	73/100	AOFAS	Low Zwipp type, Sanders Types III and IV, bilateral fractures, work-related injury
						60/130	Modified Zwipp	
						29	FFI	
						44	SF-36 PCS	
						55	SF-36 MCS	

* Categorical variables ("good/excellent") are only used if the raw scores were not provided by the authors; †Paley and Hall [43] used a medial approach for open reduction and internal fixation; NR = not reported; ST = subtalar; AOFAS = American Orthopaedic Foot and Ankle Society; PCS = physical component summary; MCS = mental component summary; SMFA = Short Musculoskeletal Functional Assessment; FFI = Foot Function Index; CC = calcaneocuboid; OA = osteoarthritis.

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