

Predicting loss of height in surgically treated displaced intra-articular fractures of the calcaneus

Manouk Backes¹ · Maarten C. Dorr¹ · Jan S. K. Luitse¹ ·
Johan C. Goslings¹ · Tim Schepers¹

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Abstract

Purpose The goal of calcaneal fracture surgery is to restore its anatomy and good foot function. However, loss of height of the subtalar joint can occur post-operatively, as expressed by a decrease in Böhler's angle (BA). The aim of this study was to identify potential factors associated with a post-operative decrease in BA.

Methods All consecutive adult patients treated with open reduction and internal fixation (ORIF) by an extended lateral approach (ELA) between 2000 and 2013 were retrospectively included. Primary outcome was the occurrence of a calcaneal collapse, defined as a postoperative decrease of $\geq 10^\circ$ in BA. The BA was measured pre-operatively, directly following surgery and at one year follow-up. Patient characteristics (body mass index, diabetes mellitus, smoking/alcohol/substance abuse, American Society of Anaesthesiologist classification), fracture classification and treatment characteristics: per-operative increase in BA and occurrence of post-operative wound infection (POWI) were collected.

Results A total of 262 patients with 276 calcaneal fractures were included. A calcaneal collapse occurred in 46 cases (17 %). The median preoperative BA, per-operative increase in BA and post-operative decrease in BA were, respectively, 2° , 27° and 4° . A calcaneal collapse was seen more often following a per-operative increase of $>25^\circ$ in BA, but no significant association was found ($p=0.056$). Uni- and multivariate analysis showed that patients with substance abuse and

those with POWI had significantly more calcaneal collapse ($p<0.05$). No association was found between substance abuse and the occurrence of POWI ($p=0.293$).

Conclusions In nearly one in six patients with an intra-articular calcaneal fracture treated with ORIF by an ELA, a post-operative collapse of $\geq 10^\circ$ was found during follow-up. Calcaneal collapse was correlated with the occurrence of a POWI and substance abuse.

Keywords Calcaneal fracture · Surgery · Böhler's angle · Extended lateral approach · Postoperative wound infection · POWI

Introduction

In 1931, Böhler proposed that radiological measurements of the calcaneus could be useful to evaluate initial damage as well as reduction quality in posterior-facet fractures of the calcaneus [4]. The Böhler's angle (BA) is the angle formed by the intersection of an imaginary line joining the highest point of the anterior calcaneal process and the highest point of the posterior talocalcaneal joint with a line drawn from the most superior point of the posterior talocalcaneal joint to the highest point of the calcaneal tuberosity measured on a lateral foot radiograph (Fig. 1). A normal BA ranges between 25 and 40° [4, 7, 29] and a BA of $\leq 20^\circ$ following trauma is highly accurate for determining the presence of a calcaneal fracture [9].

The goal of calcaneal fracture surgery is to restore the anatomy of the calcaneus with its articular surfaces and thereby maintain foot function. However, the subtalar joint frequently collapses (calcaneal collapse) post-operatively to some extent, which can be seen at radiological follow-up [11, 14, 24]. Several authors noted a correlation between initial BA and outcome [3, 10, 15, 18, 22, 24]. The BA at time of admission

✉ Manouk Backes
m.backes@amc.nl

¹ Academic Medical Center, Trauma Unit, Department of Surgery, G4, University of Amsterdam, Meibergdreef 9, PO Box 22660, 1100 DD Amsterdam, The Netherlands

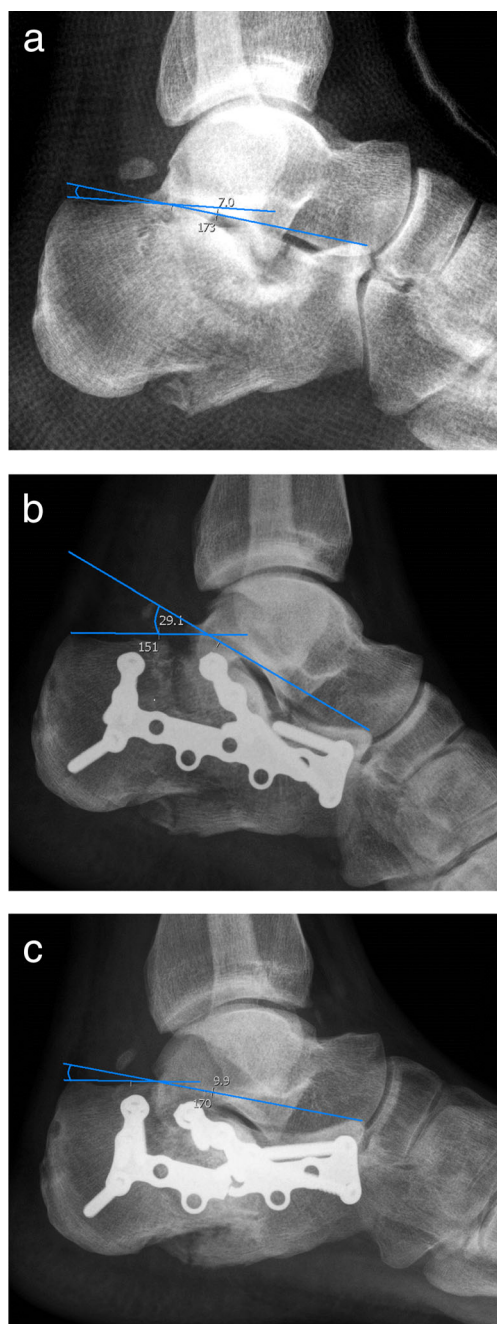


Fig. 1 Böhler's angle (BA) is the angle formed by the intersection of an imaginary line joining the highest point of the anterior calcaneal process and the highest point of the posterior talocalcaneal joint, with a line drawn from the most superior point of the posterior talocalcaneal joint to the highest point of the calcaneal tuberosity, as measured on lateral foot radiograph. **a** Preoperative BA of 7°. **b** Post-operative BA of 29°. **c** Calcaneal collapse of 10° at one year follow-up

appears to be a valuable prognosticator for functional long-term results [18]. A poor clinical outcome is more common when the BA is decreased [10]. Surgical restoration of the BA leads to a better outcome compared with non-operative treatment [15, 17]; however, operative overcorrection of a reduced BA should be avoided [18]. Patients treated conservatively

have a larger definitive reduction in BA than patients treated operatively [3].

The aim of this study was to investigate the trend in Böhler's angle in patients with a displaced intra-articular calcaneal fracture treated surgically with an extended lateral approach (ELA) and to identify factors associated with a post-operative calcaneal collapse.

Materials and methods

The hospital database of a level 1 trauma centre was used to identify patients with calcaneal fracture surgery using the appropriate procedure code. All consecutive adult patients treated with open reduction and internal fixation (ORIF) via an ELA between 2000 and 2013 were retrospectively included. Exclusion criteria were patients with an open fracture who were initially treated with external fixation prior to ORIF, surgery by a different approach than an ELA, patients with a primary subtalar arthrodesis, referred patients with a pre-existing wound infection and patients with reconstructive surgery following conservative treatment of a calcaneal fracture. Patients in whom a secondary arthrodesis was performed during follow-up were not excluded.

Primary outcome was calcaneal collapse, which was defined as a post-operative decrease of $\geq 10^\circ$ in BA. This cutoff value was chosen following an extensive literature search: in patients treated with ORIF, the highest reported decrease in BA ranged from 6 to 10.4° at 1-year follow-up [6, 11, 14] and in patients treated conservatively an 11° collapse was detected [3].

Radiographic evaluation

The BA was measured on a lateral radiograph, as described previously, at three different time points: pre-operatively, directly following surgery and at one year follow-up [22]. In patients in whom a secondary arthrodesis was deemed necessary, BA was measured prior to this procedure. All measurements were rounded to a full degree because of interobserver measurement reliability [20, 26, 29] and were made by an independent observer. A specialised trauma surgeon verified all measurements. In case of discrepancies, measurements were averaged.

Surgical procedure

The surgical procedure was performed via an ELA, in which the full-thickness flap was retracted according to the no-touch technique, with temporary K wires in the talus to facilitate operative exposure [34]. A nonlocking stainless steel AO/synthes calcaneal plate with 3.5-mm stainless steel screws (Synthes, West Chester, PA, USA) was used [2, 21, 34]. The goal of surgery was restoration of articular surfaces, calcaneal height, width, length and correction of axis. No bone grafting

or locking plates were used. Patients received a single administration of antibiotic prophylaxis preoperatively and thrombolysis prophylaxis during their 12 weeks of nonweight bearing. No postoperative casting was used, and patients were instructed to perform flexion and extension exercises of the ankle [27].

Clinical data

Data were obtained from the electronic and paper medical records. The Institutional Review Board approved the study. Patient characteristics collected were gender, age at time of operation, body mass index (BMI), presence of diabetes mellitus (DM), smoking habits, alcohol use, substance abuse and American Anaesthesiologist Association (ASA) classification. Fracture-related characteristics were pre-operative BA, which was subdivided in three groups ($<0^\circ$, $0\text{--}15^\circ$ and $>15^\circ$) [5] and fracture classification (Essex-Lopresti and Sanders). Treatment characteristics were per-operative increase in BA (post-operative BA minus pre-operative BA, subdivided into groups of $<10^\circ$, $10\text{--}25^\circ$ and $>25^\circ$), post-operative decrease in BA and occurrence of post-operative wound infection (POWI), subdivided into superficial and deep according to criteria of the United States Centers for Disease Control and Prevention [2, 16].

Statistical analyses

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 19.0 (SPSS INC., Chicago, IL, USA). Descriptive analysis was performed to assess baseline characteristics. For continuous data, medians with interquartile ranges (IQR) of $p75\text{--}p25$ or $Q3\text{--}Q1$ in nonparametric data were calculated; the Mann–Whitney U test was used for analysis. Categorical data were compared using the chi-square test, and a p value <0.05 was set as statistical significance. Firstly, a univariate analysis was performed, followed by a multivariate logistic regression analysis to model the relationship between different covariates and calcaneal collapse. Covariates with a p value <0.05 were selected for multivariate logistic regression analysis.

Results

A total of 262 patients with 276 calcaneal fractures over the 14-year study period were assessed. A post-operative calcaneal collapse of $\geq 10^\circ$ occurred in 46 cases (17%). Median pre-operative BA was 2° (IQR = $13\text{--}10$) (Fig. 2); 42% of patients had a BA of $<0^\circ$ after trauma, followed by 38% with an initial BA between 0 and 15° , and 20% with a BA of $>15^\circ$. Median per-operative increase in BA was 27° (IQR = $38\text{--}15$) and median post-operative decrease in BA in 1 year was 4° (IQR = -2 to -7); 38% of patients had a post-operative decrease in BA of $>5^\circ$ and 6% of $>15^\circ$. Calcaneal collapse was seen more often

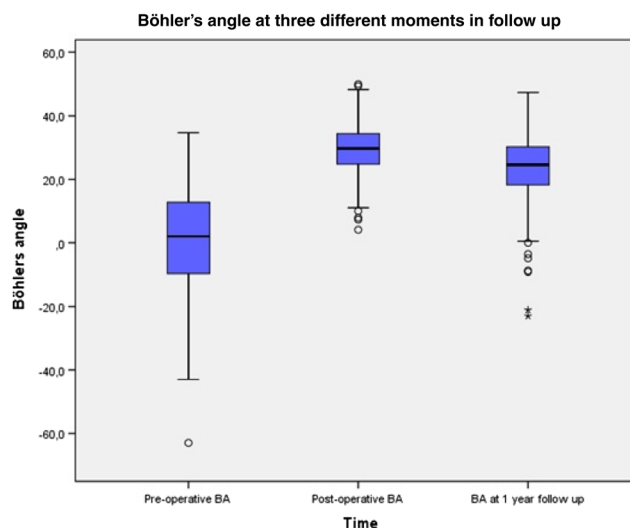


Fig. 2 Böhler's angle (BA) at three time points: median pre-operative, post-operative and at one year follow-up

following an increase of $>25^\circ$ in BA, per-operatively but no significant association was found ($p=0.056$). Patient, fracture and treatment characteristics are shown in Table 1.

Univariate analysis showed that patients who suffered from a POWI ($n=70$; 25.4%) and deep POWI ($n=34$; 12.3%) had a calcaneal collapse more frequently (respectively, $p<0.001$ and $p=0.005$). These findings remained following multivariate logistic regression analysis (respectively, $p=0.035$ and 0.004). Also, patients with substance abuse ($n=55$) had a calcaneal collapse significantly more frequent ($p=0.041$). No association was found between substance abuse and the occurrence of POWI ($p=0.293$).

Discussion

In nearly one in six surgically treated calcaneal fractures, calcaneal collapse $\geq 10^\circ$ occurred within one year, which was associated with POWI and substance abuse. Importantly, no association was found between substance abuse and the occurrence of POWI. The reason calcaneal collapse was found frequently in this cohort (17%) at one year follow-up could be because no locking plates or bone-void fillers were used during surgery. This is a limitation of our study. Locking plates may provide better stability and functional recovery [6, 8] and less decrease of BA post-operatively [15]. Autologous bone grafting may aid in achieving and maintaining restoration of calcaneal height and anatomic reduction [1]; however, no objective radiographic or functional benefits of the use of bone-graft supplementation in the operative treatment of intra-articular calcaneal fractures was found [14]. A study by Johal et al. supports the use of an injectable in situ hardening calcium phosphate paste to fill the bone void after a displaced

Table 1 Patient, fracture and treatment characteristics and incidence of calcaneal collapse in patients with calcaneal surgery

	Patients <i>n</i> (%)	Collapse (%)	No collapse (%)	<i>P</i> value (2-sided)**
Number (%)	276	46 (17)	230 (83)	NA
Male	192 (71)	33 (72)	159 (69)	0.861
Age at time of surgery (years)*	46 (35–55)	43 (34–54)	46 (35–56)	0.732
Diabetes mellitus	14 (5)	3 (2)	11 (5)	0.710
BMI*	24 (22–27)	24 (23–27)	24 (21–27)	0.168
ASA 1	184 (67)	26 (58)	158 (69)	0.165
Smoking	108 (41)	17 (40)	91 (41)	1.000
Alcohol use	145 (56)	24 (59)	121 (56)	0.864
Substance abuse	55 (22)	15 (35)	40 (20)	0.041
Fracture characteristics				
Essex-Lopresti (TT)	125 (48)	16 (35)	109 (50)	0.073
Sanders (types 1 and 2)	205 (78)	37 (80)	168 (77)	0.700
Preoperative Böhler's angle				
<0°	93 (42)	16 (40)	77 (42)	0.861
0–15°	86 (38)	19 (48)	67 (36)	0.212
>15°	45 (20)	5 (13)	40 (184)	0.275
Treatment characteristics				
Surgical increase in Böhler's angle				
<10°	29 (13)	4 (10)	25 (14)	0.795
10–25°	99 (44)	14 (35)	85 (46)	0.222
>25°	126 (56)	28 (70)	98 (53)	0.056
POWI	70 (26)	24 (52)	47 (21)	<0.001
Deep POWI	34 (12)	12 (26)	22 (10)	0.005

BMI body mass index, *ASA* American Association of Anaesthesiologists, *NA* not applicable, *N* number, *POWI* postoperative wound infection, *TT* tongue type

*Median with interquartile ranges

** Chi-square or Mann–Whitney *U* test in patients with and without postoperative collapse

intra-articular calcaneal fracture, as it shows less reduction in BA during follow-up [11].

It remains unclear how POWI is correlated with a post-operative decrease in BA. High rates of POWI were found, but numbers are in concordance with the literature on POWI following ORIF using the ELA [2, 32]. The occurrence of POWI could be the result of decreased vascularisation caused by the ELA and a calcaneal collapse due to subsequent delayed union. Shuler et al. found that patients with wound complications had a greater post-operative BA and a greater per-operative increase in BA than patients without wound complications. This is likely a result of increased tension on the wound edges [19, 23]. However, previous research by the investigators showed no correlation with the pre-operative BA or per-operative increase in BA and POWI [2]. In our study, calcaneal collapse occurred no more frequently if BA increased >25° during surgery, but no statistical significance was reached ($p=0.056$). Our standard recommendation is 12 weeks of nonweight bearing following ORIF by the ELA until fracture healing is seen on radiographs or, when in doubt, on a computed tomography (CT) scan. As calcaneal collapse

is associated with the occurrence of POWI, our data might indicate that prolonged immobilisation of these patients could be taken into consideration.

Importantly, in this study, we did not compare different surgical approaches. In current literature, a lower POWI rate of 6–14 % is reported following the sinus tarsi approach [12, 30, 31, 33]. This could be accompanied by a lower incidence of post-operative calcaneal collapse.

A calcaneal collapse in patients with substance abuse could be the result of limited compliance post-operatively, e.g. non-compliant weight bearing. However, as this was a retrospective study, we have no data to support this idea. Methods to increase fracture stability, such as primary arthrodesis, locking plates or bone-substitute materials, could be beneficial in patients in whom minimal compliance can be expected.

A general limitation of BA measurement is the risk of measurement errors due to interobserver variability or inability to correctly align the foot in standard radiographs; this misalignment can lead to errors in measurements [25, 28]. Interobserver variability in BA was classified as moderate [26] or good regarding agreement between independent observers [29].

Therefore, all radiographs were evaluated by two independent observers.

Radiographs of the contralateral calcaneus were not analysed because pre-operative templating of the uninjured contralateral calcaneus does not allow for more anatomic reduction or restoration of pre-injury morphology of the calcaneus undergoing operative fixation based on BA and calcaneal length [13].

Finally, we focused on radiographic analysis. Functional outcome, as measured using patient-reported outcome measures, was not used. Previous research showed that measurements on plain radiographs were not useful in determining outcome after intra-articular calcaneal fractures [22]. However, they are useful for determining fracture healing, alignment and surgical restoration of anatomy.

In conclusion, in nearly one in six patients with an intra-articular calcaneal fracture treated with ORIF through an ELA, a post-operative calcaneal collapse of $\geq 10^\circ$ was found during follow-up. Collapse was correlated with the occurrence of POWI and substance abuse. A post-operative CT scan may be advisable following 12 weeks of nonweight bearing to evaluate bone healing prior to weight bearing in this group of patients.

Disclosure No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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