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Review

Managing the open calcaneal fracture: A systematic review

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ABSTRACT

Introduction: Open fractures of the calcaneus are rare. They are mostly caused by high-energy trauma. There are several treatment options for calcaneal fractures. However, treatment of open calcaneal fractures might need a different approach, as open calcaneal fractures are associated with high rates of complications. The purpose of this study was to provide a literature overview on the management of open calcaneal fractures, and deduct a more standardized treatment algorithm.
Material and methods: A literature review was conducted in the databases of PubMed, EMBASE and the Cochrane Library for articles describing the management of open calcaneal fractures. Excluded were studies with less than 10 patients, studies describing combat injuries and reviews. Only articles published from 1998 to 2017 were included and there were no language restrictions.
Results: A total of 18 articles were included with 616 open calcaneal fractures in 598 patients. Most wounds were Gustilo grade III and most fractures were Sanders type III. Definitive surgery was performed after a mean of 9.8 days and in most cases in the form of ORIF via ELA. The complication rate was 21% and the mean AOFAS score was 73.7 points.
Conclusion: The complication rates of open calcaneal fractures are high and increase with the severity of the wound. A treatment algorithm is suggested. However, to produce a more evidence-based protocol and achieve consensus for treatment, additional research should be done, preferably in the form of a prospective multicenter database.

Contents

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1. Introduction

Displaced intra-articular calcaneal fractures are a life changing injury. The severity of the fracture and the complexity of treatment often leads to prolonged complaints and many do not reach pre-injury levels of work, sports and other recreational activities.

There is no single treatment that fits all calcaneal fracture. For closed fractures the number of treatment modalities seems endless. Most foot-ankle oriented trauma surgeons agree that calcaneal fractures fare better with an operative management, reserving non-operative management for less displaced fractures or patients unfit for surgery. Operative treatment usually consists of open reduction and internal fixation (ORIF). ORIF can be performed via different approaches: the extended lateral approach or the sinus tarsi approach being the most frequently used. Other operative treatments are closed reduction (with temporary Kirschner wires, percutaneous screw fixation, arthroscopically assisted, or external fixator) and primary arthrodesis following restoration of overall anatomy.

Open fractures of the calcaneus are rare. They are commonly caused by high energy trauma, like motor vehicle or motorcycle accidents or a fall from height. Because of this, there are high rates of associated injuries including polytrauma patients [1].

Complications from the traumatic wound associated with open calcaneal fractures may be severe and include infection, osteomyelitis or even amputation. As a result, the treatment of these fractures is more challenging and differs from closed fractures. The rate of post-operative wound infections (POWI) following the surgical treatment of closed calcaneal fractures ranges from about 5% deep and 15% superficial infections in large series using the extended lateral approach [2–6]. For open injuries, these rates are less well known.

The purpose of this study was to provide a literature overview on the management of open calcaneal fractures. By combining all the reported data of, often small case series due to the rarity of the injury, an improved insight on the use of different treatment modalities and complication rates of this rare injury might be achieved.

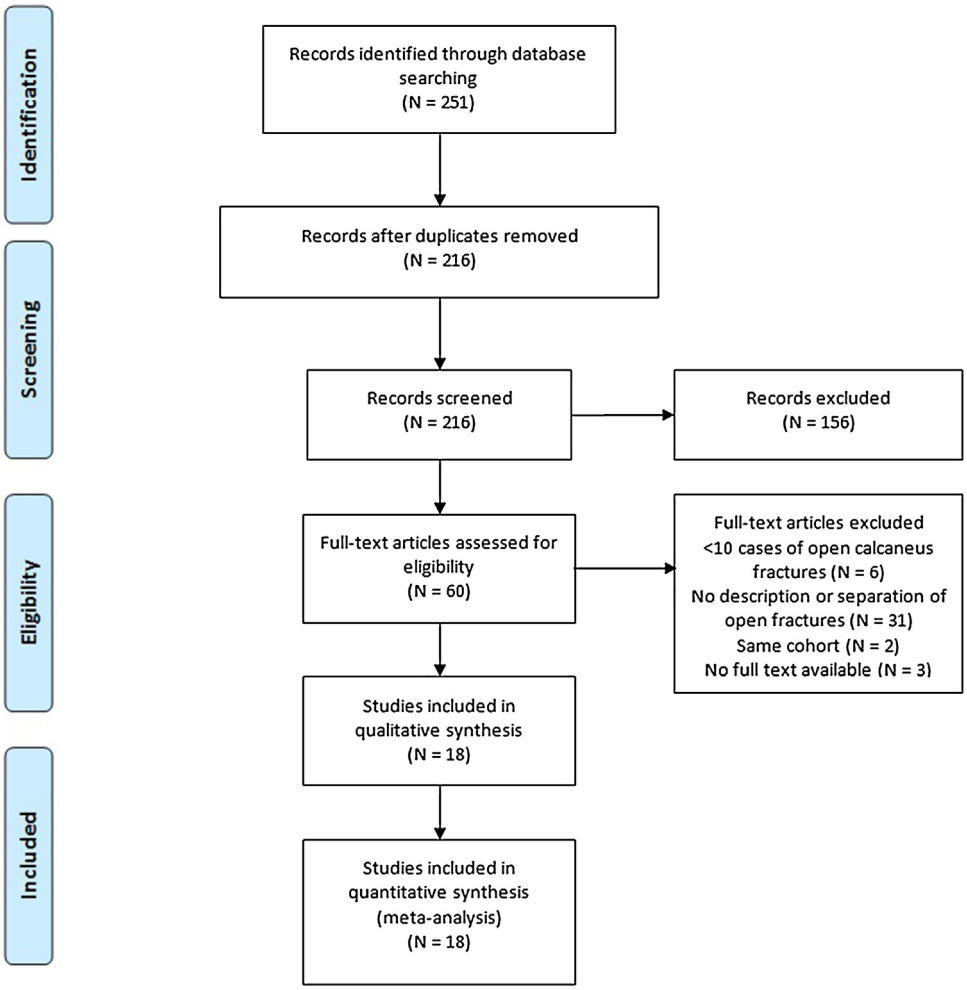

Fig.1. Flowchart of literature search.

2. Material and methods

A literature search was conducted up to November 1st 2017, to identify studies in which the management of open calcaneal fractures was described. The databases of PubMed, EMBASE and Cochrane library were explored using the following search terms: Calcaneus, Calcaneal, Fracture*, Open (Fig. 1). There were no language restrictions and only articles published after January 1st 1998 were included. In addition, a comprehensive search of reference lists of all identified articles was conducted to find additional studies.

All titles and abstracts were reviewed by two independent reviewers (KS, MM). From this selection, a list of full text articles was assessed by the same reviewers. Inclusion criteria were: (i) case series >10 patients with open calcaneal fractures, (ii) data available on the management of open calcaneus fractures. Exclusion criteria were: (v) case reports/series <10 patients, (vi) studies describing combat-related injuries, (vii) review articles, (viii) cohort already included in a different publication (ix) no specific data on open calcaneus fractures (x) no full text available. Authors of articles with no full text availability were contacted for the full text. The references were screened and added if they met the criteria. The studies were then tested for their methodological quality using the MINORS criteria. The MINORS criteria are meant to assess the quality of non-randomized trails [7].

The following data, if available, was extracted from the manuscripts.

General characteristics: study design, publication date, inclusion period in months, duration of follow-up.

Patient characteristics: number of included patients, gender and age of the patients.

Injury characteristics: number of fractures, percentage of open calcaneal fractures from the total number of calcaneal fractures, wound localization and classification (Gustilo classification [8,9]), classification of the fracture (intra- versus extra-articular, Essex-Lopresti [10], Sanders classification [11]).

Treatment characteristics: duration and type of antibiotics, surgical approach (initial and definitive), complication rate and type, and functional outcome (AOFAS score) [12].

The complications were further separated into wound infections, osteomyelitis and amputation. In the case of an amputation, there was a distinction made in primary or secondary amputations. Calcaneal fractures classified according to the OTA classification were converted to the Sanders classification using the method described in 'Fracture and dislocation compendium. Orthopaedic Trauma Association Committee for Coding and Classification' [13].

Table 1
Patient characteristics.

Author (year)	Patient characteristics				Gustilo classification						Location of wound			Intra/extra-articular		Sanders classification				Essex-Lopresti classification		
	Patients	Fractures	Male (%)	Age (years)	I	II	III	*IIIA*	*IIIB*	*IIIC*	Medial	Lateral	Other	Intra	Extra	I	II	III	IV	Tongue	JD	Comminuted
Prospective																						
Heier (2003)	42	43	66,7	40	9	8	26	12	13	1	19	5	19	34	9	2	5	9	18	NA	NA	NA
Ulusal (2008)	25	25	72	32	0	0	25	0	25	0	NA	NA	NA	15	10	NA	NA	NA	NA	NA	NA	NA
Firoozabadi (2013)	11	12	72,7	36	1	2	5	NA	NA	NA	11	0	0	NA	NA	NA	NA	NA	NA	9	3	0
Bhat (2015)	18	18	72,2	38	0	0	18	0	0	0	12	6	0	18	0	0	3	6	9	NA	NA	NA
Dhillon (2015)	16	16	62,5	33,4	0	7	9	4	5	0	16	0	0	16	0	0	7	7	0	NA	NA	NA
Zhang (2016)	31	32	71	36,4	0	0	32	25	7	0	31	0	0	NA	NA	0	21	11	0	NA	NA	NA
Li (2017)	18	18	72,2	36	8	10	0	0	0	0	NA	NA	NA	NA	NA	0	4	11	3	NA	NA	NA
Retrospective																						
Siebert (1998)	35	36	77,1	40,9	9	10	17	2	13	2	NA	NA	NA	36	0	NA	NA	NA	NA	7	23	6
Benirschke (2002)	37	39	NA	NA	4	14	21	17	4	0	NA	NA	NA	NA	NA	0	7	13	14	NA	NA	NA
Lawrence (2003)	47	48	40,4	43	NA	NA	NA	NA	NA	NA	40	4	4	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aldridge (2004)	19	19	63,2	32,7	5	8	6	1	3	2	17	0	2	16	3	0	3	10	6	NA	NA	NA
Berry (2004)	29	30	44,8	39	5	12	13	9	2	2	25	0	5	NA	NA	0	2	6	6	NA	NA	NA
Thornton (2006)	29	31	44,8	43	14	11	6	4	2	0	27	4	0	31	0	0	9	7	15	NA	NA	NA
Oznur (2007)	36	39	30,8	48,8	0	2	10	3	7	0	6	1	5	NA	NA	0	1	4	3	NA	NA	NA
Mehta (2010)	14	14	85,7	41	0	4	10	10	0	0	14	0	0	NA	NA	0	3	1	7	NA	NA	NA
Wiersema (2011)	112	115	63,3	39,7	21	43	51	23	23	5	63	18	25	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beltran (2012)	17	17	52,9	42,5	0	4	13	9	4	0	17	0	0	NA	NA	0	5	6	6	NA	NA	NA
Descriptive																						
Worsham (2016)	62	64	58,1	44,1	NA	NA	NA	*NA*	*NA*	*NA*	55	1	8	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA: not available, JD: joint depression.

Data was collected using Microsoft Excel® 2007. Only descriptive analysis was applied, including weighted averages, due to the low number of patients in some studies and the low level of evidence.

3. Results

A total of 18 articles were included in the systematic review (Fig. 1). These 18 articles had a median MINORS score of 10 (range 5–12). Worsham et al. [14] scored the lowest score of five points, because no endpoints were described. Only demographical data was extracted from this study.

3.1. General characteristics

The articles were published between 1998 and 2017. Of these, 10 articles were retrospective and seven were prospective.

3.2. Patient characteristics

A total of 616 open calcaneal fractures were described in 598 patients.

3.2.1. Prospective studies

In seven prospective studies, there were 164 calcaneal fractures in 161 patients [17,22,27,32,36–38]. They were included in a weighed period of 80 months and followed up for an average of 41.3 months. A total of 112 patients (69.6%) were male and the average age was 36.5 years.

3.2.2. Retrospective studies

In all retrospective studies, a total of 375 patients with 388 fractures were described [1,15,16,19–21,23–26]. All fractures were included in a weighed period of 121.1 months and followed up an average of 21.1 months. All, except for one retrospective study, reported data on age and gender [15]. A total of 188 patients (55.6%) were male and the average age was 41.3 years.

3.2.3. Total

Out of a total of 598 patients, with a mean age of 40.8 years, 392 (65.6%) were male (Table 1).

3.3. Wounds

The Gustilo classification was described in detail in all but two [14,15] articles. Most of the articles separated in Gustilo I, II and IIIA/B/C or Gustilo III. One article [14] did not separate the wounds into Gustilo, but they did describe that they were all Gustilo II/III. The Gustilo classification was available for 559 calcaneus fractures. In total, there were 105 (18.8%) Gustilo type I wounds, 174 (31.1%) Gustilo type II and 280 (50.1%) Gustilo type III wounds.

Four articles [1,16–18] did not describe the localization of the wound. In the other 14 articles a total of 460 wounds were specified according to their location. Of these, 355 (76.7%) were medial and 39 (8.5%) were lateral. Other descriptions were posterior (n = 14), posteromedial (n = 4), posterolateral (n = 4), plantar (n = 6), extensive (n = 14), degloving injury (n = 3), complex (n = 8), dorsolateral (n = 3) and dorsomedial (n = 1).

3.4. Fractures

Of all 18 articles, three articles [14,15,19] did not describe the classification of the fracture. Of the other 15 articles, most of them used the Sanders classification. The other studies used the Essex-Lopresti classification [16,20,21] or the OTA classification [1,22]. The fractures classified via the OTA classification were translated into Sanders classification. Based on the Sanders classification, 14 articles described a total of 300 intra-articular fractures. Aldridge et al. [23] described 19 fractures, all classified Sanders II–IV, yet they described three fractures as extra-articular. Seven articles reported a total of 22 extra-articular fractures. Out of a total of 250 fractures, four (1.6%) fractures were classified as Sanders type 1, 95 (38%) were classified as type 2, 137 (54.8%) were type 3 and 99 (39.6%) fractures were type IV. Two articles used the Essex-Lopresti classification and described a total of 48 patients. There were 16 (33.3%) tongue type fractures, 26 (54.2%) joint depression type fractures and six (12.5%) comminuted fractures.

Table 2
Prophylactics and wound treatment.

Author (year)	Prophylactics		Wound treatment
	AB	Tetanus	I&D
Prospective			
Heier (2003)	43	NS	43
Ulusal (2008)	Bacteria culture-dependent	NS	25
Firoozabadi (2013)	12	12	12
Bhat (2015)	18	NS	18
Dhillon (2015)	16	NS	16
Zhang (2016)	32	NS	32
Li (2017)	18	18	18
Retrospective			
Siebert (1998)	NS	NS	36
Benirschke (2002)	39	NS	NS
Lawrence (2003)	48	When appropriate	48
Aldridge (2004)	19	19	19
Berry (2004)	28	NS	28
Thornton (2006)	31	NS	31
Oznur (2007)	NS	NS	39
Mehta (2010)	14	14	14
Wiersema (2011)	115	Indication	115
Beltran (2012)	17	NS	17
Descriptive			
Worsham (2016)	NS	NS	64

NS: not specified, I&D: irrigation and debridement.

3.5. Prophylactics

Fifteen articles reported the usage of antibiotics. Fourteen articles administered prophylactic antibiotics to all 452 patients included, except for 2 patients described by Berry et al. [24] who had their leg amputated primarily. Ulusal et al. [17] gave antibiotics dependent on bacteria culture, but did not describe the number of patients. Only five articles reported the usage of tetanus prophylactic. Wiersema et al. [19] administered tetanus prophylactic only when indicated according to protocol, but they did not describe the number of patients with indication. Four articles [18,20,22,23] reported tetanus prophylactics for all patients. Three articles [1,14,25] did not describe any prophylactic.

3.6. Wound management

All but one article described standard use of debridement of the traumatic wound. In these articles, all patients (n = 577) received initial debridement. Benirschke and Kramer [16] only described using debridement in case of wound healing problems. Data on prophylactics and wound management is shown (Table 2).

3.7. Fracture treatment

Days from injury to final stabilization was described in seven articles (153 fractures) and ranged from 0 to 64 days, with a median of 9.8 days. Most fractures were primarily fixed with ORIF via Extended Lateral Approach (ELA) (n = 249). Other fractures treated with ORIF were approached using the Sinus Tarsi Approach (STA) (n = 16). Of 42 fractures fixed with ORIF, the approach was not reported. Sixty-three fractures were treated with cast, closed reduction was done in 40 fractures, with half of them fixated with K-wires and the other half with either external fixation (n = 10) or no fixation at all (n = 10). In total, 109 fractures were treated with external fixation, either in the form of an Ilizarov frame (n = 25) or in another form of external material. In 101 fractures the external fixation was used as definitive stabilization. Eight fractures described by Wiersema et al. [19] were temporarily stabilized by external fixation until the swelling had subsided. Fifteen fractures were reportedly treated percutaneously and 16 fractures were fixated via Minimally Invasive Surgery (MIS). Beltran and Collinge [26] reported 17 fractures which they fixated internally through the medial wound. Fifteen patients were treated by primary arthrodesis and seven patients needed an amputation as first treatment. Ultimately, 33 patients (6.9%) were described to have received amputation at final follow-up, including the primary amputations (Table 3).

3.8. Outcome

Seven articles described the outcome using the American Orthopaedic Foot and Ankle Society (AOFAS) questionnaire [12]. The scores ranged from 59.4 to 84, with a median of 73.7 points. Zhang et al. [27] did not describe the outcome in scores. They reported 17 feet as excellent and 8 feet as good.

3.9. Complications

All but one article [14] described wound infections (Table 4). The studies reporting complications are divided as per their study design.

3.9.1. Prospective

In the prospective articles, 43 cases (26.2%) of post-operative wound infections were mentioned. Osteomyelitis was mentioned in four articles and occurred in 15 cases (13.4%). Only three articles described a total of nine cases (10.3%) of amputations.

Table 3
Fracture treatment.

Author (year)	Days BS	Fracture treatment								
		ELA	MW	STA	PR	NO	PA	EF	PC	NS
Prospective										
Heier (2003)	7,3 (0–51)	9				14	11	1		
Ulusal (2008)	NS							25	1	17
Firoozabadi (2013)	33 (12–64)	10			2					
Bhat (2015)	NS							18		
Dhillon (2015)	10,56				9			7		
Zhang (2016)	NS	16		16						
Li (2017)	0							18		18
Retrospective										
Siebert (1998)	NS	6			19	11		10		
Benirschke (2002)	NS	39								
Lawrence (2003)	NS				9		1			10
Aldridge (2004)	7 (0–22)	17				2				
Berry (2004)	NS	6			10					
Thornton (2006)	NS	31								
Oznur (2007)	NS	6				2	3	5	2	
Mehta (2010)	18 (10–28)	14								
Wiersema (2011)	NS	73				34		8		
Beltran (2012)	NS		17							
Descriptive										
Worsham (2016)	NS				15			15		7

Days BS: days before definitive surgery, ORIF: open reduction, internal fixation, ELA: ORIF via extensile lateral approach, NS: ORIF, incision not specified, MW: ORIF via medial wound, STA: ORIF via sinus tarsi approach, MIS: minimally invasive surgery, PR: percutaneous reposition, NO: non-operatively, PA: primary arthrodesis, LF: limited fixation, EF: external fixation, PC: (partial) calcanectomy, NS: not specified.

3.9.2. Retrospective

A total of 76 cases (19.6%) of post-operative wound infections were described and six articles described 28 fractures (11%) that developed osteomyelitis. A total of 20 cases (7.2%) were described to have had an amputation.

3.9.3. Total

The most complications appeared in fractures with a Gustilo grade IIIC open wound (66.7%). In open calcaneal fractures with a Gustilo type I open wound the lowest complication rate was reported (11.8%).

4. Treatment algorithm

The treatment protocol for open calcaneal fractures, analogue to open fractures in general, should include early admission of a first generation cephalosporin with Gentamycin added in the grade-3 open wounds. Antibiotics are continued for 72 h. Wounds are inspected once in the Emergency Department, photographed, and coved in sterile gausses. Patient are scheduled for emergency wash-out and debridement in theatre. The medial wounds are caused by the medial sustentaculum fragment, therefore a reduction of the fracture is of paramount importance to relieve stress on the medial wounds and to allow tension free closure. The tuber and sustentaculum are well accessible via the medial wound and fixated using 1.6 mm Kirschner wires from tuber into the sustentaculum fragment and if needed into the talus. An additional Essex-Lopresti maneuver might be necessary to reduce a tongue-type calcaneal fracture using a Schanz pin from posterior. This restores height and axial alignment. In case of severe instability (due to additional injuries) an external fixator could be added. We prefer pin placement at the already injured side (usually medially) from tuber to tibia to cuneiform or first metatarsal. The

Table 4
Complications.

Author (year)	Complications		Amputations		
	Wound infection	Osteomyelitis	Primary	Secondary	Total
Prospective					
Heier (2003)	8	8	2	4	6
Ulusal (2008)	3	1	0	0	0
Firoozabadi (2013)	5	5	0	2	2
Bhat (2015)	10	NS	0	0	0
Dhillon (2015)	7	NS	0	0	0
Zhang (2016)	3	1	0	1	1
Li (2017)	6	0	0	0	0
Retrospective					
Siebert (1998)	23	14	1	4	5
Benirschke (2002)	2	NS	0	0	0
Lawrence (2003)	2	0	2	1	3
Aldridge (2004)	2	2	0	1	1
Berry (2004)	2	NS	2	0	2
Thornton (2006)	7	2	0	2	2
Oznur (2007)	8	3	0	0	0
Mehta (2010)	1	1	0	0	0
Wiersema (2011)	25	6	0	6	6
Beltran (2012)	2	NS	0	0	0
Descriptive					
Worsham (2016)	NS	NS	NS	NS	5

NS: not specified.

department of plastic surgery are consulted in case of Grade-3 wounds. The wound is closed if possible and a vacuum assisted closure device is placed over the closed incision with a silicone-sheet between the black sponge and skin. Inspection of the wound is done regularly and repeated debridement is perform on demand. Post-operatively a CT-scan is made and, if needed, definitive fixation is done via a sinus tarsi approach after approximately seven days. In case of severe cartilage damage a primary arthrodesis is performed via the same incision. Wound edge necrosis on the medial side occurs frequently, this is however well treated by VAC and subsequent split skin graft if needed.

5. Discussion

This review was set up to obtain a broader view of the management of open calcaneal fractures and the associated outcome and complications. A total of 18 articles were included in this review with a MINORS score ranging from 5 to 12 out of 16.

Of all fractures described using the Sanders classification, four (1.6%) fractures were classified as Sanders type 1, 95 (38%) were classified as type 2, 137 (54.8%) were type 3 and 99 (39.6%) fractures were type IV. These percentages do not match those of a large study by Sanders describing only closed calcaneal fractures [28]. Sanders et al. described a total of 108 closed calcaneal fractures. The largest percentage of fractures were classified as Sanders type II (64.8%). Which is a similar percentage of Sanders type II fractures as reported by Backes et al. (66.1%) [29]. The difference in overall Sanders classification can be explained by the fact that the trauma is usually of higher impact when an open fracture is present, so logically fractures tend to have a higher Sanders classification.

In this review, a median duration of 9.8 days was found between the injury and final stabilization. This delay is most likely due to the time it takes before the soft tissues had settled down. In studies concerning closed calcaneal fractures treated with the extended lateral approach these delays have been reported as well. For example, Jin et al. [30] found 6 days between injury and final stabilization in 64 closed calcaneal fractures, Backes et al. [29] described 14 days between injury and surgery and Rammelt et al. found 10.2 days delay [5]. Different delays have been reported for different surgical approaches [31].

Definitive surgery was done mostly by ORIF via ELA (40.4%), only a small amount of fractures (2.6%) were fixed by ORIF via STA. Despite upcoming evidence of lower rates of complications in closed calcaneal fractures, only one article [27] used the STA. More research in the usage of STA in open calcaneal fractures is warranted.

As expected, the complication rate of the open fractures described in this review is higher than that of closed fractures described in other reviews [32,33]. The highest rate of infections was seen in grade III C wounds (37.5%), as well as the highest rate of amputations (37.5%). The lowest rate of infections was seen in grade I wounds (9.6%). Unfortunately, most studies did not report definitive treatment per patient or per grade of open injury.

Treating more severe open calcaneal fractures with less invasive techniques versus the other way around might be a confounding factor. It is well known that the infection rate is higher in open calcaneal fractures than in closed calcaneal fractures [34]. The highest rate of infections occurred in fractures that were fixated with external fixation (55.7%) and the highest rate of amputations occurred in fractures that were treated with closed reduction (10.3%). An explanation might be that these fractures had more severe wounds or fractures or developed an infection early precluding definitive internal fixation.

In addition, a surprisingly low complication rate in the group of fractures treated with ORIF via ELA (13.5%) was found. The ELA is well known for its high complication rates [6], as is described in a large review describing the post-operative wound infections of 8584 closed calcaneal fractures. This is the reason why the STA is gaining interest in the treatment of displaced calcaneal fractures [35]. A reason for the lower complication rate in the ELA group could be that this incision was mostly used in open fractures with a low-grade wound.

The complication rate was higher in the prospective articles than in the retrospective articles. This seems to be contradictive since the more recent studies are all prospective. An explanation could be that documentation of complications in the prospective trails was better. Another reason may be that follow-up was not

sufficient in the retrospective group. There were two studies [10,11] in which the follow-up period was not described, one study had a 75% of follow-up [24], in the remaining studies a 100% follow-up was reported.

Because of the low incidence of open calcaneal fractures, the total amount of included fractures still is not large. Therefore, the results of this review should be interpreted with caution. None of the studies included are randomized controlled trials. Most of the articles are done retrospectively, meaning that not every patient was treated according to one protocol. This ensures a lot of variability in treatment, meaning the outcomes are not comparable to each other and should not be considered as such.

A treatment algorithm based on available literature, which acts as the protocol in our hospital, is presented. More research about this topic is necessary to reach a consensus for optimal treatment of open calcaneal fractures. The ideal study design would be a randomized controlled trial, to minimize variability in comorbidities and treatment, and to detect differences between multiple types of fixation. However, we expect that this will not be feasible due to the low incidence of open calcaneus fractures. Alternatively, a prospective, multicenter (international) database to collect data on treatment of open calcaneal fractures should be initiated.

6. Conclusion

This review was conducted to provide a literature overview on the management of open calcaneal fractures. This review found that the complication rate increases with the severity of the wound. Because of the high rate of complications, surgical treatment should be directed consistently at preventing infection. A treatment algorithm is presented based on available literature. However, more data is needed.

Conflicts of interest

No conflicts of interest were reported by any of the authors.

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