

## Fractures to the anterior process of the calcaneus – Clinical results following functional treatment

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### ABSTRACT

**Background:** Fractures to the anterior process of the calcaneus (APC) have long been considered rare injuries. Although recent studies have reported a higher incidence, these injuries have yet received little attention in clinical research. Only few case reports/series, all suffering multiple methodical shortcomings, exist. The aim of this study was to objectively evaluate the outcome after fractures to the APC treated by full weight bearing and to investigate the influence of fracture characteristics.

**Methods:** Retrospective register study with prospective follow-up. Adults with acute unilateral fractures to the APC and concomitant injuries limited to the Chopart joint line, treated by full weight-bearing, with a follow-up of  $\geq 12$  months were included. Fracture characteristics (Degan classification, displacement, intra-articular involvement, comminution) were assessed in CT scans. Return to work (RTW) / sports (RTS), Visual Analogue Scale Foot and Ankle (VAS-FA), Karlsson Score and the 12-Item Short-Form Health Survey (SF-12) were assessed. The influence of age, sex, fracture type/characteristics, and concomitant injuries on the outcome parameters was analyzed.

**Results:** 27 patients (38 years, IQR 29–58), 74% female with a median follow up of 24 months (IQR 16–41) were included. 56% of the fractures were non-displaced and 82% comminuted. 48% were type I, 33% type II and 19% type III according to Degan. 78% of the patients suffered concomitant injuries of the Chopart joint line. Median RTW was 14 days (IQR 10–42), and RTS 90 days (IQR 30–180). The clinical outcome resulted in a median overall VAS-FA of 95 (IQR 89–98), Karlsson Score of 90 (IQR 82–100) and SF-12 PCS of 56 (IQR 53–58) / SF-12 MCS 55 (48–58).

**Conclusion:** Functional treatment of fractures to the anterior process of the calcaneus yielded good to excellent results and a fast return to work in the vast majority of patients. Yet, a prolonged return to sports was noted. No significant differences regarding the outcome were observed when comparing the different fracture types or any other fracture characteristic assessed.

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### Introduction

The anterior process of the calcaneus (APC) is a saddle-shaped promontory at the anterior aspect of the calcaneus with varying length, breadth and shape. It forms the anterior part of the subtalar joint, the superior-posterior part of the calcaneal-cuboid joint (CC joint) and acts as point of insertion for the extensor digitorum et hallucis brevis muscles, the dorsal calcaneocuboid ligament (laterally), and the bifurcate ligament (medio-centrally). The bifurcate

ligament originates from the centro-medial aspect of the APC and reaches to the navicular as well as to the cuboid bone and is suspected to be an important stabilizer of the Chopart joint line [1–4].

Fractures to the anterior process of the calcaneus (APC) have been considered rare injuries, as up to 88% are missed on plane radiographs [5]. Due to the increasing availability of computed tomography (CT) [2,3,6–8], recent studies showed that APC fractures account for 3–23% of all extra-articular calcaneus fractures [2,4]. Moreover, it has been estimated that 2–5% of all ankle sprains are associated with a fracture to the APC [5,9]. The exact mechanism of injury is unknown. It has been hypothesized, that inversion and plantar flexion results in avulsion fractures of the APC [2,6,10]. On the other hand other authors concluded that dorsiflexion and eversion leads to compression of the APC between cuboid and talus (“nutcracker”-injury) [2,11]. Most classifications for calcaneus

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fractures, such as the AO-Classification [12], the Essex-Lopresti-Classification [13], or the Sanders Classification [14], do not or just partially describe APC fractures. The most commonly applied classification for APC fractures is the classification by Degan et al. [2] (Fig. 1). Based on plain radiographs, it differentiates three different types: Type I represents extraarticular, undisplaced avulsion fractures; Type II are displaced, extra-articular fractures; Type III are large(r) intra-articular APC fractures. Limitations of this classification are, that it does neither take account of the location (lateral, central, medial) nor the extend of the fracture.

Depending on the size and location of the fracture to the APC, it can affect the CC joint and might even affect the stability of the Chopart joint. Since the first descriptions in literature in 1931 by Dachtler and Christopher [15,16], only few case reports and case series with a broad diversity of treatment recommendations have been published. The heterogeneous treatment approaches include non-operative treatment ranging from unrestricted full weight-bearing to immobilization and non-weight bearing for up to 10 weeks. Other authors recommended surgical treatment by open reduction and internal fixation or open respectively arthroscopic excision [2,4,6,8,10,17]. All these studies are missing inclusion criteria, objective outcome measures, and a detailed fracture assessment by CT [8]. Due to the limited evidence available, evidence-based treatment recommendations are currently not available. With no evidence by hand arguing for surgical treatment of any Degan type APC fracture, the authors treat all patients suffering a fracture of the APC (without Chopart dislocation) non-operatively by unrestricted full weight-bearing as tolerated.

The primary aim of this study was to evaluate the patient subjective outcome of APC fractures treated by full weight-bearing. The secondary aim was to identify factors affecting the outcome of nonoperative treated APC fractures.

## Materials and methods

### Study design

The study is a retrospective registry study with a prospective follow-up. It was approved by the local ethical committee of the Ludwig-Maximilians-University of Munich (# 660-16).

### Patient selection

The study was conducted at a level 1 trauma center. Patient suffering an APC fracture between 03/2011 and 03/2016 were identified through the clinical and radiological databases. The radiological database was searched using the following terms: "Proc\* AND ant\* AND fracture". The clinical database was searched for the ICD-10 S92.0 (International Classification of Diseases, Version 2013). The results of this database search were independently reviewed by two investigators (FKM, SFB). Only non-operatively treated patients suffering an acute, isolated, unilateral fracture to the APC without Chopart joint dislocation and a follow-up of at least 12 months were included in the final analysis. The detailed inclusion and exclusion criteria are presented in Table 1.

**Table 1**  
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
- Age $\geq$ 18 years	- Skeletally immature patients
- Unilateral acute fracture to the APC	- Bilateral injuries
- No concomitant injuries except to the Chopart joint	- Concomitant injuries besides the Chopart joint
- PROM Follow up $\geq$ 12 months	- Chopart joint dislocation
- X-ray and CT-scan available	- Pathologic or non-traumatic fractures
- Functional treatment	- Unable to follow treatment regime
- Informed consent	

### Treatment regimen

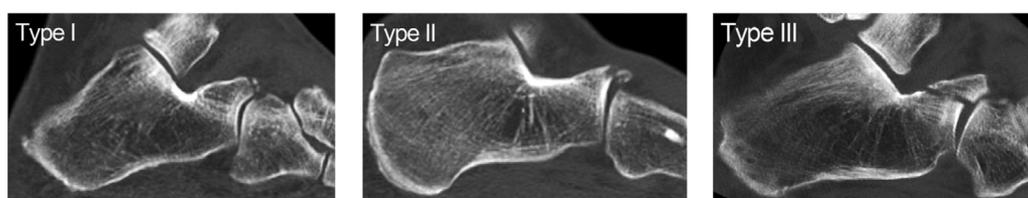
All patients included in this study were treated non-operatively. Patients were instructed to conduct full weight-bearing as tolerated. In case of severe swelling and / or pain, patients were immobilized in a walker or cast with partial weight-bearing on crutches for a maximum of two weeks. Once full weight-bearing was possible additional physiotherapeutic treatment was initiated. Radiological follow-up was conducted only in case of pain or functional limitations in everyday activities for more than six weeks.

### Data collection - retrospective

Demographics, smoking, and return to work / sports were collected retrospectively from the patients' records. Fracture classification and -characteristics were assessed on the CT scans, independently by two investigators (FKM, SFB). Possible disagreement was resolved by discussion. All fractures were classified according to Degan et al. [2] (Fig. 1). Fracture characteristics assessed were displacement ( $<2$  mm,  $>2$  mm), location (medial, medial + intermediate, intermediate, lateral + intermediate, lateral, complete), and comminution (simple, multifragmentary). Further, the type and number of concomitant injuries within the Chopart joint line were assessed.

### Data collection - prospective

Two validated foot and ankle specific patient reported outcome measures (VAS-FA, Karlsson Score) and a quality of life score (SF-12) were assessed prospectively based on a postal questionnaire. The VAS-FA [18] is based on the visual analogue scale, assessing 20 items in four domains (function, pain, other complaints, overall). Scores range from 0 to 100, while 100 represents the best outcome. The standard population scores 82–100 in pain, 87–100 in function, 68–83 in other complaints and 86–100 overall. The Karlsson Score [19] comprises of eight items and scores can range from 0 to 100 (no impairment). Scores between 91–100 represent an excellent, 81–91 a good, 61–80 a fair, and below 60 a poor outcome. The SF-12 (Version 2, license number: QM038796) [20] is a short version of the 36-Item Short-Form Health Survey (SF-36) scoring in two domains, the Mental Component Summary (MCS) and the Physical



**Fig. 1.** Degan Classification.  
Type I: small and undisplaced fracture; Type II: displaced, extra-articular fracture; Type III: large intra-articular fracture [2].

**Table 2**  
Collected Demographics and Objective Outcome Measures.

Patients' records	Outcome scores
Demographics: Age, Sex, smoking	VAS-FA (Pain, function, other compl., overall) [21]
Classification: Degan Classification	Karlsson Score [22]
Fracture characteristics: displacement, localization, comminution	SF-12 (MCS, PCS) [42]
Concomitant injuries within Chopart joint line	
Return to work (RTW)	
Return to sports (RTS)	

VAS-FA=Visual Analogue Scale Foot and Ankle [21], SF-12=12-Item Short Form Survey V2, PCS=Physical Health Composite Scores, MSC=Mental Health Composite Scores [42].

Component Summary (PCS). Both range between values of 0–100 with a score of 50 representing values of a standard population [21] (Table 2).

*Outcome variables*

The primary aim was the assessment of the patient subjective outcome after functionally treated APC fractures. The primary outcome parameter was return to work (RTW). Return to sports (RTS), VAS-FA [18], the Karlsson Score [19] and the SF-12 [20] were secondary outcome parameters. The second aim was the identification of variables affecting the patient subjective outcome. Therefore, the influence of demographics, fracture type, fracture characteristics, number and type of concomitant injuries (independent variables) on the patient subjective outcome was assessed.

*Statistics*

The D'Agostino & Pearson normality test on RTW revealed no normal distribution (p=0.007). The non-parametric statistical analysis included standard descriptive statistics (median and interquartile range (IQR)), Mann-Whitney-U-Test, Spearman's correlation, and Kruskal-Wallis ANOVA. The level of significance for the primary outcome parameter was set at p≤0.05. Due to multiple testing, an alpha-level correction (Bonferroni) was conducted for

the secondary outcome parameters, setting the level of significance to p≤0.007. Statistics were computed using SPSS (Version 22, IBM, Armonk, United States).

**Results**

*Patient selection and demographics*

The patient selection is outlined in Fig. 2. The database searches identified 781 patients, 64 patients were eligible, seven refused participation and 27 patients (47%) completed the final follow-up. The median age of all patients was 38 years (IQR 29–58 years), 74% were female and 22% smokers. The median follow-up was 24 months (IQR 16–41 months).

*Fracture classification and characteristics*

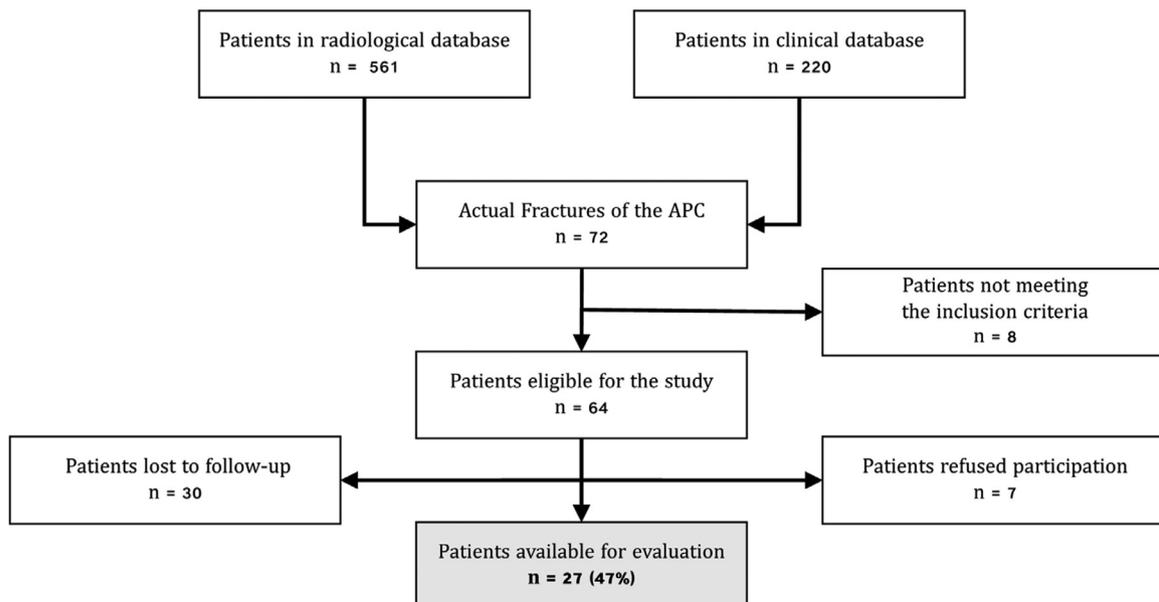
52% of the APC fractures occurred on the left foot. According to Degan [2] 48% were classified as type I, 33% as type II and 19% as type III fractures. 56% of the fractures were non-displaced, 82% comminuted, and 74% extraarticular. The complete width of the APC was involved in 52%, the lateral part in 15%, the lateral and intermediate party in 29%, the medial and intermediate part in one patient (4%). Isolated medial fractures were not observed.

**Concomitant injuries**

Concomitant injuries within the Chopart joint line occurred in 78% of the patients. These included avulsion fractures to the talonavicular joint (TN) in 52%, to the calcaneo-cuboidal joint (CC) in 59%, as well as fractures of the navicular bone (7%), and the cuboid bone (4%). Of all patients, 30% suffered one, 33% two, and two patients (7%) each three or four concomitant injuries. The fracture characteristics and concomitant injuries per the fracture type are displayed in Table 3.

*Return to work / sports and PROM*

Return to work (RTW) occurred after a median time of 14 days (IQR 10–42 days), return to sports (RTS, preinjury level) after



**Fig. 2.** Patient selection. n = number.

**Table 3**  
Fracture characteristics and concomitant injuries.

	Degan Type I	Degan Type II	Degan Type III
Fracture characteristics			
Displaced	–	33% (n=9)	11% (n=3)
Comminuted	37% (n=10)	33% (n=9)	11% (n=3)
Intraarticular	–	–	19% (n=5)
Concomitant injuries within Chopart joint line			
Avulsion TN	22% (n=6)	19% (n=5)	11% (n=3)
Avulsion CC	37% (n=10)	19% (n=5)	4% (n=1)
Fracture navicular	–	4% (n=1)	4% (n=1)
Fracture cuboid	–	4% (n=1)	–

90 days (IQR 30–180 days). The median follow up was 24 months (IQR 16–41 months). At final-follow-up, the patients reached a median VAS-FA overall score of 95 points (IQR 89–98 points), 96 points (IQR 89–100 points) for pain, 97 points for function (IQR 91–98 points) and 97 points (IQR 88–100 points) for other complaints. 85% of the patients had a VAS-FA overall score equivalent to a healthy population [18]. The median Karlsson score was 90 points (IQR 82–100 points). Of all patients 48% achieved an excellent (91–100 points), 29% a good (81–90 points), 19% a fair (61–80 points) and one (4%) a poor result (< 60 points). For the quality of life (SF-12), the PCS was 56 (IQR 53–58) and the MCS 55 (IQR 48–58). 78% were in the range of the standard population for the SF-12 PCS and 67% for the SF-12 MCS [21]. All subjective outcome parameters per patient are illustrated in Supplementary Table 1.

#### Variables influencing the outcome

Neither sex, nor age, or the individual risk factor smoking had a significant ( $p$ -value > 0.05) influence on any subjective outcome measure. All primary and secondary outcome parameters (RTW, RTS, VAS-FA, Karlsson Score, SF-12) were analyzed in regard to the influence of the fracture type (Degan Type I, Type II, Type III; Table 4) and the fracture characteristics (displacement, localization, comminution, concomitant injuries within Chopart joint line; Table 5). Again, none of the assessed fracture characteristics had a significant ( $p$ -value > 0.05) influence on any outcome parameter.

#### Discussion

Fractures to the anterior process of the calcaneus (APC) have been considered rare injuries and have received little attention in clinical research until today [2,6,8,9]. Only few retrospective case reports and case series are available reporting the results after APC fractures. Next to their low level of evidence, all of these are inherent of various shortcomings. First, in the vast majority of studies the fractures were neither classified nor clearly described [2,17,22,23]. Second, various studies included both patients with acute fractures as well as patients with prolonged symptoms [2,10]. Third, in only one study objective outcome measures were assessed [10]. All other studies provided a subjective outcome only. Fourth, the treatment regimens applied, even within

the same study, varied considerably and ranging from immobilization in a lower leg cast (2–10 weeks) to early functional treatment with full weight-bearing. Fifth, many studies relied on x-rays only and did not routinely perform CT scans. Despite these major limitations, recent studies have tried to propose treatment approaches [6] for APC fractures. Still, the authors strongly believe, that the data available today do not allow to conclude an evidence-based treatment algorithm for fractures to the APC.

Therefore, the aim of this study was first to evaluate the subjective patient outcome of fractures to the APC when treated functionally by full weight bearing. The second aim was to identify, whether certain fracture characteristics feature a different prognosis with this treatment regime. To the authors' knowledge, this is the first study providing a detailed CT based fracture analysis and classification including a homogeneous patient collective with acute fractures only, applying a standardized treatment regime and analyzing the outcome using validated PROMs. Overall, the herein presented study found functional treatment to result in a fast return to work (Median 14 days, IQR 10–42) and good to excellent clinical results in the vast majority of all patients for the VAS-FA (Overall median score 95 points, IQR 89–98), the Karlsson score (Median of 90 points, IQR 82–100) and both, the PCS (Median 56, IQR 53–58) and the MCS (Median 55, IQR 48–58) of the SF-12. Still, return to sports with a median of 90 days (IQR 30–180) might be considered prolonged. Seven patients reported an unsatisfactory result in at least one of the PROMs, but only one patient in all three PROMs (Patient #10). Three patients demonstrated inferior results only in the Karlsson Score but reached excellent results for the VAS-FA, the SF-12, and a quick RTW and RTS. One patient achieved an inferior result for the SF-12 but excellent results for the VAS-FA and the Karlsson score. Twelve patients reported a RTS greater than 100 days, but only one patient showed an inferior result for the Karlsson Score. All of the other eleven patients featured excellent outcome parameters despite the prolonged time to RTS. For example, patient #3 reported the longest RTS (730 days) but demonstrated excellent results for all PROMs (Karlsson Score, VAS-FA, SF-12). Despite of the use of well validated PROMs, some incongruency between these was observed in a subset of patients.

In this study a remarkably high proportion of the patients were female (74%). Interestingly, this is in line with previous studies [17,22,24]. Some authors have therefore hypothesized that wearing high-heeled shoes might predispose for sustaining a fracture to the APC as the combination of inversion and plantar-flexion of the foot has been hypothesized to lead to fractures of the APC [22,24]. Controversy, dorsiflexion and eversion have been discussed to result in a compression between cuboid and talus and thereby to fracture the APC. Unfortunately, none of these concepts is based on biomechanical or objective studies. Therefore, the exact mechanism of injury is still a matter of debate. The higher proportion of females could also be the result of females being better responders than males or of both, the mechanism of injury in combination with a higher responsiveness of the female patients.

The results of this study are difficult to be compared to previous studies, as it is the only one to assess validated PROMs.

**Table 4**  
Influence of Fracture Type on Outcome Parameters.

	n	RTW [d]	RTS [d]	VAS-FA Overall	Karlsson Score	SF-12 PCS	SF-12 MCS
Overall	27	14 (10–42)	90 (30–180)	95 (89–98)	90 (82–100)	56 (53–58)	55 (48–58)
Degan Type I	13	14 (12–41)	40 (28–180)	95 (84–98)	95 (83–100)	56 (51–58)	52(44–59)
Degan Type II	9	14 (5–49)	90 (49–180)	97 (89–97)	85 (75–95)	56 (53–59)	55 (50–58)
Degan Type III	5	14 (7–54)	79 (42–455)	95 (93–99)	90 (78–98)	56 (40–56)	57 (47–61)
<i>p</i> -value		0.922	0.759	0.737	0.369	0.546	0.555

Values are given as median and interquartile range (IQR); d = days, RTW = Return to work, RTS = Return to sport, VAS-FA = Visual Analogue Scale Foot and Ankle [21], SF-12 PCS = SF-12 Physical Health Composite Scores, SF-12 MCS = SF-12 Mental Health Composite Scores [42].

**Table 5**  
Influence of Fracture Characteristics on Outcome Parameters.

	n	RTW [d]	RTS [d]	VAS-FA Overall	Karlsson Score	SF-12 PCS	SF-12 MCS
Overall	27	14 (7-35)	90 (70-199)	95 (88-95)	90 (81-93)	56 (51-56)	55 (50-55)
Extraarticular	20	14 (8-42)	90 (30-180)	95 (89-97)	91 (83-100)	56 (53-59)	53 (48-58)
Intraarticular	7	14 (10-17)	79 (28-365)	95 (92-99)	90 (77-100)	53 (48-59)	56 (41-60)
<i>p-value</i>		0.725	0.607	0.570	0.893	0.063	1.000
Simple	5	10 (5-39)	180 (43-548)	95 (94-97)	95 (86-100)	57 (44-58)	57 (54-63)
Comminuted	22	14 (13-42)	85 (28-180)	95 (88-98)	90 (77-100)	56 (52-58)	52 (45-58)
<i>p-value</i>		0.447	0.186	0.739	0.377	0.650	0.064
Not dislocated	15	14 (10-40)	56 (28-180)	95 (88-97)	92 (82-100)	56 (49-58)	52 (45-60)
dislocated	12	14 (6-53)	90 (46-180)	95 (89-99)	88 (78-97)	56 (53-58)	55 (48-58)
<i>p-value</i>		1.000	0.829	0.755	0.373	1.000	0.905
Complete	14	23 (13-46)	165 (53-195)	95 (92-98)	90 (84-96)	56 (52-57)	57 (47-60)
Lateral	4	27 (9-27)	110 (21-319)	96 (71-98)	98 (44-100)	55 (42-57)	50 (44-60)
Lateral + inter.	8	14 (6-14)	43 (28-135)	94 (83-97)	84 (71-100)	57 (50-59)	53 (48-58)
Medial + inter.	1	4	14	99	100	57	52
<i>p-value</i>		0.202	0.113	0.495	0.474	0.766	0.936

Values are given as median and interquartile range (IQR); d = days, RTW = Return to work, RTS = Return to sport, VAS-FA = Visual Analogue Scale Foot and Ankle [21], SF-12 PCS = SF-12 Physical Health Composite Scores, SF-12 MCS = SF-12 Mental Health Composite Scores [42].

Ochman et al. [10] reported the results of five patients with Degan Type III fractures treated by open reduction and internal fixation, but only three patients suffered an acute isolated fracture. They reported an average American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score (AOFAS) [25] of 91.4 (Range 72–100), representing a good to excellent outcome. Still, it is well accepted, that the AOFAS is poorly validated [26]. All other published studies on APC fractures solely reported the subjective outcome with “satisfying” clinical results [2], described the course of healing as “uneventful”, or stated the radiological outcome only [2,11,27].

Although most of the studies available did not specify the exact fracture types included, almost all authors appear to favor non-operative treatment for Degan type I and II fractures [2,6,17,22–24]. Yet, the non-operative treatment regimens varied significantly. Most authors favored immobilization in a lower leg cast and non-weight bearing prescribing crutches for four to six weeks and report satisfying outcomes [23]. Others applied partial weightbearing without immobilization [27]. On the contrary, one study, including nine patients, encouraged full-weight bearing [17] and also reported satisfying outcomes. Surgical treatment by open reduction and internal fixation has been described primarily for large and dislocated APC fractures (Degan type III) [10,28]. Surgical excision has been considered mainly in patients with symptomatic non-union following non-operative treatment [2,4]. In the study presented herein, 13 fractures Degan type I, nine type II, and five type III were included. All featured comparable good results following functional treated by full weight-bearing with no significant differences regarding the Degan classification. Out of the seven patients with an unsatisfactory result in one or more outcome parameters, three suffered a Degan type I, two a type II and two a type III fracture. It is notable that patients suffering a type Degan III fracture required a mean time of more than 200 days to RTS compared to 123 days for type I and 116 for type two fractures. Yet, these differences did not reach a level of significance. When analyzing patients with an RTS of more than 100 days, again no differences could be observed between the different fracture types.

Due to a lack of objectified biomechanical analyses, the exact mechanism of fractures to the APC is elusive. It has been hypothesized that these fractures reflect an avulsion presumably of the bifurcate ligament. This mechanism would also explain the concomitant injuries to other parts of the Chopart complex. Concomitant injuries within the Chopart-joint line have been reported in previous studies. A MRI study analyzing fractures to the APC reported accompanying injuries to the talo-navicular joint in 76% and to the calcaneo-cuboidal joint in 100% [7] which compares favorably to

the herein identified 78%. These concomitant injuries most likely reflect injuries to the joint capsule and ligaments and therefore most notably represent a soft tissue injury to the Chopart complex. This might be one of the reasons why, in some cases, the time to return to sports was prolonged. The current study could not show a significant influence of these concomitant injuries on the subjective patient outcome. Yet, the high incidence of concomitant injuries might be the reason why neither characteristics, nor symptoms or outcomes could be assigned to any particular injury. The influence of these injuries on the stability of the Chopart joint is still unknown [29], as no consensus exists on how to assess instability, neither by clinical examination nor by radiography. Still, the authors believe this to be of major interest as instability is known to significantly impair function [30]. While Degan et al. in 1982 [2] focused on the bony injury solely, today it seems comprehensible that the fractures reflect the visualization of a complex soft tissue injury to the Chopart joint line. Consequently, future studies should focus on biomechanical analyses of the different stabilizers of the Chopart joint complex, assessing the mechanism of trauma and thereby the exact structures being injured. Further objectified measures must be established to identify an instability within the Chopart joint line. This might help in identifying injuries prone to inferior outcome when treated functionally. These patients could require a more restrictive treatment strategy or even surgical treatment. To answer this key question biomechanical as well as larger comparative studies are required.

The herein presented study has several strengths and limitations which should be discussed. To the authors' knowledge, this study is among the largest case series reporting on the outcome of APC fractures. No other study has presented a comparably detailed analysis and description of the actual fracture types and characteristics based on CT scans. Furthermore, only acute fractures to the APC were included. Previous studies usually comprised of an inhomogeneous collective of acute fractures and symptomatic non-unions [2,4,10,22]. Additionally, it is the first study using validated patient rated outcome measures for all patients following a standardized treatment regime. A final strength is the median follow up of 24 months (IQR 16–41 months), which compares favorably to previous studies [4,27].

A major limitation is the retrospective patient selection despite the prospective follow-up. This also contributes to the limited follow-up rate of 47% of all eligible patients. The fate of the remaining 53% of the patients remains unknown. In the worst case, they did not respond because of inferior results. Nevertheless, this is a common limitation of retrospective studies. While Carey et al.

[22] reported a follow-up rate of 65% for their patients and Degan et al. [2] were able to follow up all their patients, the vast majority of studies did not provide any information regarding the patient selection or the follow-up rate [22,24]. Another limitation is a missing radiographic follow up for the majority of the patients. Consecutive radiographs were only acquired if patients reported prolonged symptoms for more than six weeks. Of those patients receiving a radiographic follow-up, no non-union could be observed. This leaves the risk of asymptomatic non-unions in the group of patients without radiological follow-up. Still the authors believe that asymptomatic non-unions of the APC are of no clinical importance. Although the study is among the largest case series, the number of 27 patients still remains small. Finally, the study lacks a comparison group.

## Conclusion

Based on the subjective outcome of 27 patients suffering a APC fracture, functional treatment of these fractures yielded good to excellent results and a fast return to work in the majority of patients. Neither the fracture type and characteristics, nor concomitant injuries within the Chopart joint had a significant influence on the outcome. Yet, several patients required more than three months to return to their preinjury level of activity.

## Conflict of interest

The authors declare that there is no conflict of interests.

## Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Ethics

This study is conducted according to the principles of the Declaration of Helsinki (Version 9, 10/08, Seoul) and in accordance with the Medical Research Involving Human Subjects Act. The Ethical Committee of the Medical Faculty of the Ludwig-Maximilians-University of Munich approved the study at the Department of General, Reconstructive and Trauma Surgery (# 660-16). All patients included in our study provided written informed consent to participate.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.injury.2019.06.008>.

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