

Calcaneocuboid Joint Involvement in Calcaneal Fractures-CT Based Analysis and Classification

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Abstract

Background: This retrospective radiographic study sought to evaluate how calcaneocuboid joint (CCJ) involvement relates to the pattern and severity of intraarticular calcaneal fractures.

Methods: Preoperative computed tomography scans with axial, coronal and sagittal reformations of 100 displaced intraarticular calcaneal fractures (87 patients) were evaluated for: Bohler's angle, Sanders, Zwipp and Eastwood/Atkins classifications, and calcaneocuboid, anterior, or middle subtalar articular involvement. Primary fracture line location and extension into the CCJ was measured on axial, coronal and sagittal computed tomography views. Number and orientation of fracture lines were analyzed. A classification of CCJ involvement is proposed.

Results: CCJ involvement was 84%. There were 41.2% Sanders type II (28.4% IIA, 8.4% IIB, 8.4% IIC), 37.9% type III (21.1% IIIAB, 10.5% IIIAC, 6.3% IIIBC) and 16.8% type IV fractures. The mean Bohler's angle was $8.9^{\circ} \pm 19.4^{\circ}$ degrees. The mean primary fracture line extended into the lateral third of the CCJ in 29.3%, to the middle third in 50.9% and into the medial third in 20.8%. A vertical fracture line was observed in 69.5%, an oblique fracture line (superior-lateral to inferior-medial) in 19.9%, a horizontal fracture line in 2.4% and a multifragmentary situation in 7.3%. Statistical analysis found significant associations between CCJ involvement and Sanders Classification ($rs=0.274$; $p<.001$) or Bohler's angle ($rs=-0.204$; $p=0.005$), as well as location of the vertical fracture line ($rs=0.386$; $p<0.005$).

Conclusion: These results suggest that calcaneocuboid joint involvement is associated with more severe calcaneal fractures, and a typical fracture pattern can be expected. A classification of CCJ involvement is proposed.

Keywords: Calcaneal fracture; Calcaneocuboid joint involvement; Fracture morphology; CT scan; Fracture classification

Level of Evidence

Level III, retrospective cohort study

Introduction

Calcaneocuboid joint (CCJ) involvement has been shown to play an important role in calcaneal fractures [1-3]. Calcaneal fractures with CCJ involvement are associated with more severe trauma and worse outcome [3]. Hence, the calcaneocuboid should attract our interest during surgery. However, our understanding of CCJ involvement is still scarce. Only a handful of studies address this issue [3].

This does not only concern treatment and outcome, but also fracture pathology and classification [4-6]. Biomechanics and fracture pathology of the posterior facet have been described in detail [7,4]. But if it comes to the anterior apophyseal region even nomenclature becomes inconsistent. It is referred to as "anterior process" or "head of calcaneus". The apophyseal region is separated from the tuberosity (thalamic region) by Wards' neutral triangle, and consists of primary compressive and secondary tensile trabeculae (Figure 1) [8]. Extension of the primary fracture line into the CCJ has been described by Silhanek et al. [4]. They portrayed in their retrospective study that calcaneal fractures exhibiting a medial primary fracture line are associated with a more severe fracture pattern and an increased incidence of anterior articular extension. However, they lack to be more specific about CCJ involvement. A more precise analysis of CCJ involvement was presented by Ebraheim et al. [1,2]. They could show that CCJ involvement is more common with joint depression type fractures, and extension of the fracture line into the CCJ should be suspected in presence of significant

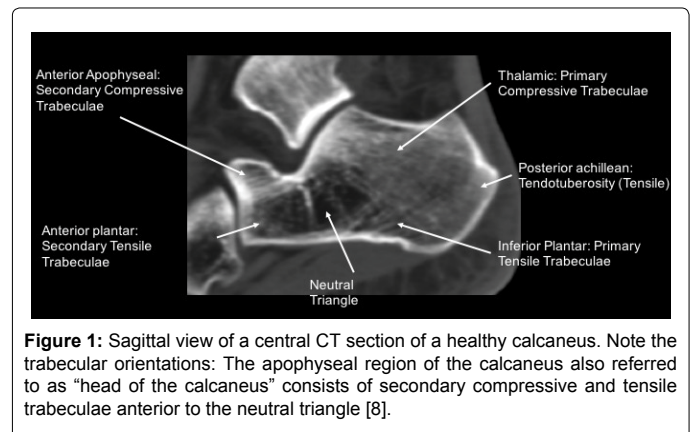


Figure 1: Sagittal view of a central CT section of a healthy calcaneus. Note the trabecular orientations: The apophyseal region of the calcaneus also referred to as "head of the calcaneus" consists of secondary compressive and tensile trabeculae anterior to the neutral triangle [8].

lateral column comminution or lateral talar subluxation. However, their findings are based mainly on coronal CT scans.

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Therefore, the aim of this study was to describe CCJ involvement and fracture pathology of the “calcaneal head” more precisely. A secondary research question was to evaluate the need of a separate classification of the CCJ injuries.

Methodology

After approval by the internal review board (IRB) 100 CT-data-sets of 87 consecutive patients were analyzed retrospectively.

Inclusion criteria

Displaced intraarticular calcaneal fractures (at least one articular surface of the calcaneus had to be involved), age equal or above 18 years. Bilateral fractures, concomitant injuries or multiple injuries were not considered as exclusion criteria.

Exclusion criteria

Insufficient CT-data-set, e.g. missing reformations.

Standard CT scans were obtained using spiral-CT (“Sensation 16”, Siemens, Germany) with table feed of 3 mm/s, slice collimation of 0.75 mm, pitch factor of 0.65 and slice thickness of 2 mm. Axial, sagittal and coronal reformations were obtained of each fracture. Axial views were reconstructed parallel to the sole of the foot, sagittal views orthograde to the ankle joint and the coronal views parallel to the calcaneocuboid joint (CCJ).

Demographic data of the patients were obtained from the clinical database (age, gender, injury mechanism, side of injury).

CT scans were analyzed systematically including the criteria displayed in Table 1 with a specific focus on CCJ involvement. These included: Analysis of number of fracture lines (using axial, sagittal and coronal views), localization of sagittal fracture line (on axial view), extension of primary fracture line into the CCJ, and orientation of fracture lines (vertical, horizontal oblique, multi-fragmentary; primarily on coronal views (Figure 2).

In addition, we tried to classify the CCJ injury (adapted from Sanders’ Classification of calcaneal fractures). Non-displaced fractures irrespective on the number of fracture lines were classified as type I. Two and three-part fracture as type II and III respectively, and multi-fragmentary fractures as type IV. The location of the fracture line was noted A=Lateral to C=Medial (Table 2).

Statistical analysis

Data are reported either as mean and standard deviation (SD) or median and range. Statistical analysis was performed using SPSS 25.0. Parametric and non-parametric statistical tests (Pearson and Spearman’s Rank Correlation Coefficient and Pearson’s Chi-square) were used to determine a meaningful association or difference between the parameters and groups where indicated. Statistical significance was assumed with $p < 0.05$.

Analysis of CT Scans	
Bohler’s angle (on central sagittal view)	
Estimated shortening of the calcaneus (on axial view)	
no shortening	
mild shortening, up to 10%	
moderate shortening up to 30%	
severe shortening >30%	
Axial deformation (varus or valgus): longitudinal axis [°]	
Size of central defect (axial views)	
no defect	
small defect $\leq 3 \text{ cm}^2$	
medium size defect $>3 \text{ cm}^2 \leq 6 \text{ cm}^2$	
large defect $>6 \text{ cm}^2$	
Fracture and displacement of the articular surfaces: posterior, medial and anterior facet of the subtalar joint and the calcaneocuboid joint	
no displacement	
<2 mm	
>2 and ≤ 5	
≥ 5 mm	
Fracture classification	
Essex-Lopresti	
Sanders	
Eastwood/Atkins	
Zwipp	
Evaluation of calcaneocuboid joint	
No of fracture lines	
Orientation and localization of fracture lines (axial, coronal and sagittal views)	
Analysis of primary fracture line (axial view, in [%] from lateral to medial)	
Classification of CCJ fracture (provisionally)	
Type I: non-displaced fracture	
Type II: displaced two-part fracture	
Type IIA-C	
Type III: displaced three-part fracture	
Type IIIAB-BC	
Type IV: multifragmentary	

Table 1: Analysis of CT scans (Axial, Coronal and Sagittal views).

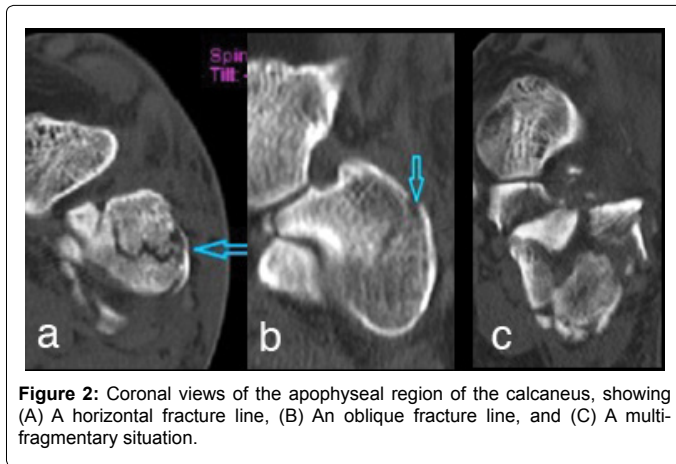


Figure 2: Coronal views of the apophyseal region of the calcaneus, showing (A) A horizontal fracture line, (B) An oblique fracture line, and (C) A multi-fragmentary situation.


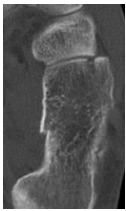



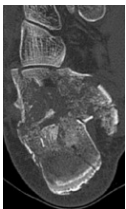
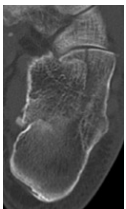
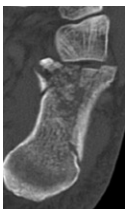
Type	Axial view		
I			
II			
			
			

Table 2: Proposed classification of CCJ involvement in calcaneal fractures, adapted from Sanders Classification system. Axial views of the spiral-CT scans were used to evaluate the CCJ.

Results

Epidemiological data

A total of 87 patients were included into the study. 13 patients (15%) had bilateral calcaneal fractures. The left side was involved

in 51 cases and in 49 cases the right side. Only 13 of the 87 patients were female (15%). The mean age was 43.75 ± 13.36 years. The most common injury mechanism was a fall from height (n=70; 79%), 8% (n=7) occurred during a motor vehicle accident and 13% (n=11) of the fractures were caused by other mechanisms (e.g. Distortion of the foot and ankle, direct trauma due to a heavy load (crush injury).

Fracture morphology

Mean Bohler's angle was $8.9^\circ (\pm 19.4^\circ)$. Fracture morphology is displayed in Table 3a. The most common fracture type involved 3 joints with a medium size central defect and a moderate shortening of the heel. The posterior facet was severely displaced in 55.7%, whereas displacement of the medial and anterior facet was generally only slight. The CCJ was involved in 84% with moderate (35.7%) or severe (38.1%) displacement.

70% were joint depression type of injuries, whereas 30% were classified as tongue type according to the Essex-Lopresti classification system. Sanders and Zwipp Classifications are displayed in Table 3b. Mean Zwipp Scale was 9.5 points (range, 4-12 points). Using the Eastwood/Atkins Classification system 16.8% classified as type I, 47.4% as type II, and 35.8% as type III.

Calcaneocuboid joint involvement

51.2% of the 84 fractures with CCJ involvement showed one fracture line, 40.5% two, and 1.2% three. In 7.1% a multifragmentary situation was present. Displacement of the fragments was <2 mm in 20.2%, >2 and <5 mm in 35.7% and >5 mm in 38.1%.

In the majority of the cases (69.5%) a vertical fracture line was present (based on the coronal view, followed by an oblique fracture line extending from superior-lateral to infero-medial. Horizontal fracture lines were present in 2.4% and in 1.2% the fracture line extended from superior-medial to infero-lateral (Figure 3).

Based on the axial reformations the primary fracture line extended into lateral third of the CCJ in the in 28.2%, into the middle third in 50.9%, and in 20.8% into the medial third.

Evaluation of meaningful associations between the parameters

Table 4 displays a correlation matrix of the most important parameters analyzed. Significant correlations were found between CCJ involvement and general severity of the fracture, i.e. number of facets involved ($rs=0.446, p<0.001$), or size of central defect ($rs=0.454, p<0.001$).

Table 5 displays a contingency table showing the association between the extension of the primary fracture line into the CCJ and the number of facets involved, Zwipp and Sanders classifications. Overall fracture classification was found to be more severe (e.g. 9-12 points on the Zwipp scale) the more medial the primary fracture line extended into the CCJ (Spearman Rank Correlation Coefficient $rs=0.386, p=0.004$).

No clear association, however, was found between the orientation of the fracture line and fracture classification (Zwipp scale; Spearman Rank Correlation Coefficient $rs=0.122, p=0.233$).

Finally, a classification of the CCJ involvement is proposed. Figure

Bohler's angle (n=99)	>20° 31	11°-20° 37	0°-10° 21	<0° 10
Shortening (n=100)	Non 2	Mild/small 31	Moderate/medium 49	Large 18
Central defect size (n=100)	Non 8	Mild/small 21	Moderate/medium 37	Large 34
Facets involved (n=100)	1 8	2 32	3 42	4 18
Facet involved [%]	No displacement	Displacement <2 mm	Displacement >2 mm <5 mm	Displacement >5 mm
Posterior (97%)	2.1	8.2	34	55.7
Medial (61%)	12.9	53.2	21	12.9
Anterior (28%)	17.9	46.4	17.9	17.9
CCJ (84%)	6	20.2	35.7	38.1
No. of fracture lines CCJ [%], n=84	1 51.2	2 40.5	3 1.2	Multifragmentary 7.1
Extension of prim. fx line into CCJ [%], n=53	Lateral 1/3 28.2	Middle 1/3 50.9	Medial 1/3 20.8	-
Orientation of CCJ fracture line [%], n=98	Vertical 69.5	Oblique superiorlateral-inferiormedial 19.5	Oblique superiormedial-inferiorlateral 1.2	Horizontal 2.4

Table 3a: Fracture morphology.

Sanders Classification									
Fracture Type (n=95) [%]	IIA	IIB	IIC	IIIB	IIIC	IIIBC	IV		
	28.4	8.4	8.4	21.1	10.5	6.3	16.8		
Zwipp Classification									
Points (n=100)	4	6	7	8	9	10	11	12	n
n	1	4	3	13	30	26	13	10	100

Table 3b: Sanders and Zwipp classifications.

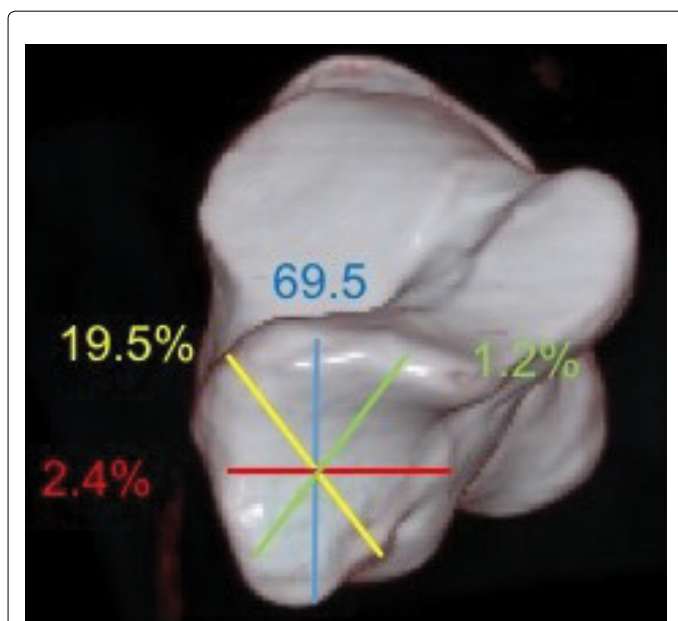


Figure 3: 3D-CT (Volume rendering technology, VRT) of the "head of the calcaneus", displaying the orientation of the primary fracture line extending into the CCJ.

4 shows the distribution of the fractures according to this system. We found a significant correlation of the CCJ fracture classification and Sanders, or Zwipp Classifications (Table 4).

Discussion

Epidemiological data on calcaneocuboid joint involvement in intraarticular calcaneal fractures is scarce. This retrospective radiographic evaluation sought to describe calcaneocuboid joint involvement in more detail than previous studies, including our own [3]. CCJ involvement was 84 % in this study. In a prior study, we reported 68% [3]. Other studies reported a lower incidence ranging from 33% to 76% [1,9-14,4]. The higher incidence in comparison to other studies might be explained by the fact, that only intraarticular calcaneal fractures were included into this study. In contrast to other studies we included all fractures involving the CCJ, even if non-displaced (also in contrast to our previous study [3]). Furthermore, the reported incidences are based on different diagnostic algorithms. Not all studies included routinely CT-scans with multiplanar reformations to evaluate calcaneal fractures. Most studies lack to define CCJ involvement exactly. Last but not least, there were more Sanders type III and IV fractures in our cohort compared to other studies [4,15].

Up to now fracture anatomy of the anterior apophyseal region of the calcaneus and the calcaneocuboid joint is only partially understood

	Bohler's angle	Shortening	No of facets involved	Displacement med. facet	Displacement ant. Facet	Classification (Zwipp)	Classification (Essex-Lopresti)	Classification (Sanders)	Classification (Eastwood/Atkins)	Soft tissue	Fracture line CCJ	Central defect	Classification CCJ
Bohler's angle	Rs	-0.493**	-0.272**	-0.126	-0.155	-0.355**	0.155	-0.272**	-0.433**	-0.182	-0.204*	-0.206*	-0.224*
	Sig.	0	0.006	0.216	0.126	0	0.139	0.008	0	0.076	0.043	0.043	0.027
Shortening	N	99	99	99	99	99	92	94	95	96	99	97	98
	Rs	-0.493**	1	0.133	-0.016	0.411**	0.272**	0.325**	0.421**	0.054	0.147	0.387**	0.158
No of facets involved	Sig.	0	0.188	0.551	0.873	0	0.008	0.001	0	0.6	0.143	0	0.119
	N	100	100	100	100	100	93	95	95	97	100	98	99
Displacement med. facet	Rs	-0.272**	0.133	0.613**	0.656**	0.733**	-0.072	0.281**	0.099	0.035	0.446**	0.318**	0.500**
	Sig.	0.006	0.188	0	0	0	0.495	0.006	0.338	0.733	0	0.001	0
Displacement ant. facet	N	100	100	100	100	100	93	95	95	97	100	98	99
	Rs	0.216	0.06	1	0.155	0.392**	-0.079	0.185	0.072	0.098	0.046	0.169	0.123
Classification (Zwipp)	Sig.	0.551	0	0.123	0.123	0	0.449	0.072	0.488	0.337	0.651	0.096	0.225
	N	100	100	100	100	100	93	95	95	97	100	98	99
Classification (Sanders)	Rs	-0.155	-0.016	0.155	0.571**	1	0.029	0.285**	0.069	0.1	0.316**	0.207*	0.253*
	Sig.	0.873	0	0.123	0	0	0.786	0.005	0.507	0.329	0.001	0.041	0.011
Classification (Essex-Lopresti)	N	100	100	100	100	100	93	95	95	97	100	98	99
	Rs	-0.355**	0.411**	0.733**	0.392**	0.571**	0.02	0.596**	0.257*	0.19	0.440**	0.284**	0.497**
Classification (Eastwood/Atkins)	Sig.	0	0	0	0	1	0.851	0	0.012	0.063	0	0.005	0
	N	100	100	100	100	100	93	95	95	97	100	98	99
Soft tissue	Rs	0.155	0.272**	-0.079	0.029	0.02	1	0.039	0.089	0.088	0.122	0.14	0.05
	Sig.	0.008	0.001	0.072	0.005	0	0.714	0.352**	1	0.340**	0.144	0.055	0.222*
Fracture line CCJ	N	94	95	95	95	95	91	95	94	92	95	93	94
	Rs	-0.204*	0.421**	0.099	0.069	0.257*	0.089	0.352**	0	0.001	0.165	0.602	0.032
Central defect	Sig.	0	0	0.338	0.488	0.012	0.399	0	0.165	0.001	0.165	0.602	0.032
	N	95	95	95	95	95	91	94	95	92	95	93	94
Classification (CCJ)	Rs	-0.182	0.054	0.035	0.098	0.19	0.088	0.314**	0.340**	1	0.298**	0.162	0.317
	Sig.	0.076	0.6	0.733	0.337	0.063	0.411	0.002	0.001	0	0.003	0.117	0.002
Fracture line CCJ	N	96	97	97	97	97	90	92	92	97	97	95	96
	Rs	-0.204*	0.147	0.446**	0.046	0.316**	0.122	0.274*	0.144	0.298**	1	0.454**	0.939**
Central defect	Sig.	0.043	0.143	0	0.651	0	0.244	0.007	0.165	0.003	0	0	0
	N	99	100	100	100	100	93	95	95	97	100	98	99
Classification (CCJ)	Rs	-0.206*	0.387**	0.318**	0.169	0.284**	0.14	0.132	0.055	0.162	0.454**	1	0.386**
	Sig.	0.043	0	0.001	0.096	0.041	0.005	0.186	0.602	0.117	0	0	0
Classification (CCJ)	N	97	98	98	98	98	91	93	95	95	98	98	97
	Rs	-0.224*	0.158	0.500**	0.123	0.253*	0.05	0.309**	0.222*	0.317**	0.939**	0.386**	1
Classification (CCJ)	Sig.	0.027	0.119	0	0.225	0.011	0.633	0.002	0.032	0.002	0	0	0
	N	98	99	99	99	99	92	94	94	96	99	97	99

Table 4: Associations between the most important parameters analyzed in a correlation matrix. Showing spearman's rank correlation coefficient Rs and level of significance.

Extension of primary fracture line into CCJ / No facets involved. Zwipp and Sanders' Classifications	Lateral Third	Middle Third	Medial Third	Spearman Correlation Coefficient [$r_s(p)$]
Facets involved				0.3 (<0.05)
1	0	0	0	
2	6	10	1	
3	8	14	7	
4	1	3	3	
Zwipp Classification				0.426 -0.01
0-5 points	0	0	0	
6-9 points	10	13	2	
10-12 points	5	14	9	
Sanders' Classification				0.396 -0.01
Typ I	0	0	0	
Typ II	10	14	2	
Typ III	3	11	6	
Typ IV	2	1	2	

Table 5: Contingency table: association between the extension of the primary fracture line into the CCJ and the no. of facets involved, Zwipp and Sanders classifications

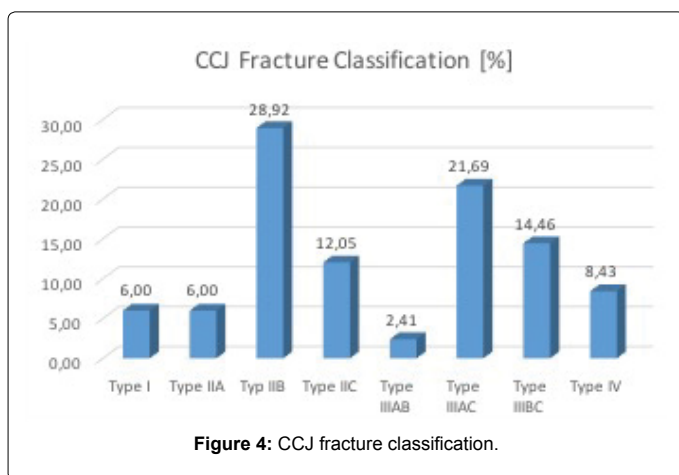


Figure 4: CCJ fracture classification.

and most classification systems disregard CCJ involvement. Therefore, we provided a detailed analysis of fracture morphology.

As we could show CCJ involvement was associated to more severe trauma, resulting in a significant higher Zwipp or Sanders classification. This has partially been shown previously [3,16].

Ebraheim et al. described the correlation between joint depression type fracture and calcaneocuboid involvement [1]. Our data confirmed also this finding.

These (more severe) fractures were also more likely to be displaced (Spearman rank correlation coefficient, $r_s=0.512$, $p<0.001$) and presented either with a vertical fracture line, an oblique fracture line extending from super-lateral to inferior-medial, or a multifragmentary situations. These typical extension of fracture lines into the CCJ may be explained by the proposed typical patho mechanisms with the talus acting as an “axe” during the vertical impact and producing a more or less vertical fracture line, that runs more medially with more varus position of the foot during impact [17,18]. We could also show that a more severe fracture, defined by a higher Sanders or Zwipp

classification, was associated with a more medial extension of the primary fracture line into the CCJ. This compares to the findings of Silhanec et al. [4].

Sanders classification itself, however, is inapplicable to classify CCJ involvement, since only subtalar joint involvement is assessed [19].

We therefore proposed a classification system for CCJ involvement, based on our descriptive data. During analysis, we could show a reasonable correlation between our own CCJ classification and Sander’s Classification for calcaneal fractures. Significant correlations were also seen for Bohler’s angle, number of facet involved, degree of displacement, Zwipp classification and size of the central defect (Table 3).

Future studies must show, if the proposed classification system has any impact on the treatment and outcome of calcaneal fractures. Moreover, intra and interobserver reliability have to be tested. Last but not least, this additional classification system has to show, if it is applicable in daily routine.

In the light of outcome measurements, we concluded in a prior study, that CCJ involvement should be given more credit during surgery and in our research efforts [3]. Therefore, an accurate radiological analysis is indispensable.

Limitations of this study include a not always optimal imaging, which is especially true for the coronal reformations, resulting in images that could not be included for analysis. Even if trained on a regular basis, secondary reformations of the original data-set were not always satisfactory.

Moreover, we have to take into account a low inter- and intra-observer reliability. Roll et al. could show that the extension into the CCJ was evaluated correctly only in 49% [20].

Conclusion

Our results suggest that calcaneocuboid joint involvement is more common than previously published and associated with more severe calcaneal fractures, as shown by Sanders and Zwipp classifications.

Typical fracture patterns can be expected, facilitating planning for surgical reduction and fixation. A classification of CCJ involvement may support our efforts towards a better understanding of fracture pathology.

Conflicts of Interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of the article "Calcaneocuboid Joint Involvement in Calcaneal fractures-CT Based Analysis and Classification".

References

1. Ebraheim NA, Biyani A, Padanilam T, Christiansen G (1996) Calcaneocuboid joint involvement in calcaneal fractures. *Foot Ankle Int* 17: 563-565.
2. Ebraheim NA, Haman SP, Lu J, Padanilam TG (1999) Radiographic evaluation of the calcaneocuboid joint: a cadaver study. *Foot Ankle Int* 20: 178-181.
3. Kinner B, Schieder S, Muller F, Pannek A, Roll C (2010) Calcaneocuboid joint involvement in calcaneal fractures. *J Trauma* 68: 1192-1199.
4. Silhanek AD, Ramdass R, Lombardi CM (2006) The effect of primary fracture line location on the pattern and severity of intraarticular calcaneal fractures: A retrospective radiographic study. *J Foot Ankle Surg* 45: 211-219.
5. Zwipp H, Baumgart F, Cronier P, Jorda E, Klaue K, et al. (2004) Integral classification of injuries (ICI) to the bones, joints, and ligaments: Application to injuries of the foot. *Injury* 35: 3-9.
6. Kinner BJ, Best R, Falk K, Thon KP (2002) Is there a reliable outcome measurement for displaced intra-articular calcaneal fractures? *J Trauma* 53: 1094-1101.
7. Andermahr J, Jesch AB, Helling HJ, Jubel A, Fischbach R, et al. (2002) CT morphometry for calcaneal fractures and comparison of the Zwipp and Sanders classifications. *Z Orthop Ihre Grenzgeb* 140: 339-346.
8. Bajraliu M, Walley KC, Kwon JY (2016) Rationale for the hypodense calcaneal region of ward's neutral triangle. *Orthop J Harv Med Sch* 17: 63-67.
9. Gupta A, Ghalambor N, Nihal A, Trepman E (2003) The modified Palmer lateral approach for calcaneal fractures: wound healing and postoperative computed tomographic evaluation of fracture reduction. *Foot Ankle Int* 24: 744-753.
10. Linsenmaier U, Brunner U, Schoning A, Rieger J, Krotz M, et al. (2003) Classification of calcaneal fractures by spiral computed tomography: Implications for surgical treatment. *Eur Radiol* 13: 2315-2322.
11. Hutchinson F, Huebner MK (1994) Treatment of os calcis fractures by open reduction and internal fixation. *Foot Ankle Int* 15: 225-232.
12. Kurozumi T, Jinno Y, Sato T, Inoue H, Aitani T, et al. (2003) Open reduction for intra-articular calcaneal fractures: Evaluation using computed tomography. *Foot Ankle Int* 24: 942-948.
13. Stephanson JR (1987) Treatment of displaced intra-articular fractures of the calcaneus using medial and lateral approaches, internal fixation, and early motion. *J Bone Joint Surg Am* 69: 115-130.
14. Zwipp H, Rammelt S, Barthel S (2004) Calcaneal fractures: Open reduction and internal fixation (ORIF). *Injury* 35: 46-54.
15. Cao L, Peng Y, Yan R, Wang H (2013) Surgical treatment of calcaneal fracture involving talocalcaneal and calcaneocuboid joints. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 27: 169-172.
16. Miric A, Patterson BM (1998) Pathoanatomy of intra-articular fractures of the calcaneus. *J Bone Joint Surg Am* 80: 207-212.
17. Burdeaux BD (1983) Reduction of calcaneal fractures by the McReynolds medial approach technique and its experimental basis. *Clin Orthop Relat Res* 177: 87-103.
18. Carr JB (1993) Mechanism and pathoanatomy of the intraarticular calcaneal fracture. *Clin Orthop Relat Res* 290: 36-40.
19. Sanders R, Fortin P, DiPasquale T, Walling A (1993) Operative treatment in 120 displaced intraarticular calcaneal fractures. Results using a prognostic computed tomography scan classification. *Clin Orthop Relat Res* 290: 87-95.
20. Roll C, Schirmbeck J, Schreyer A, Muller F, Neumann C, et al. (2011) How reliable are CT scans for the evaluation of calcaneal fractures? *Arch Orthop Trauma Surg* 131: 1397-1403.