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Avulsion Fractures of Posterior Calcaneal Tuberosity: Identification of Prognostic Factors and Classification

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ABSTRACT

Avulsion fractures of the posterior calcaneal tuberosity are rare injuries, and little is known about the underlying factors, outcomes, and prognosis. Furthermore, classifications described previously focus on fracture morphology, with uncertain clinical utility. We present the results of a retrospective study of 21 patients treated for this pathology from January 2002 to December 2015. Features analyzed were age; sex; mechanism of injury; medical comorbidities; type of fracture, as proposed by Beavis; fracture displacement; fragment size; type of treatment; complications; need for secondary surgery; and the American Orthopaedic Foot and Ankle Society score after treatment and follow-up care. Mean age was 56.95 years. A total of 61.9% were females, and 71.4% were secondary to low-energy trauma. In addition, 19% were diabetic. Mean follow-up was 57.24 months. Surgery was performed in 81%. Complications rate was 61.9%, and secondary surgery was needed in 38.1%. Mean fracture displacement was significantly higher when complications occurred (25.91 mm versus 7.61 mm) ($p = .03$) and when soft tissues complications appeared (30.65 mm versus 14.68 mm) ($p = .02$). Female gender was associated with the secondary loss of reduction ($p = .04$). The Beavis classification was not related significantly with any outcome variable. When fracture displacement was ≥ 2 cm, complication rate increased from 30% to 90.9% ($p = .008$) and soft tissue compromise increased from 0% to 45.45% ($p = .035$). A new classification system with prognostic value is described, based on fracture displacement. We present 1 of the largest series published to date; fracture displacement is a major variable that influences the outcomes of these injuries, and a new classification attending to a prognostic factor is developed.

The calcaneus is the most frequently fractured bone in the foot, accounting for 1.2% of all fractures in the body (1), of which 60% to 75% are intra-articular (2). Axial loading is the most common mechanism of injury, whereas twisting forces result in the majority of extra-articular fractures. Avulsion fractures of the posterior calcaneal tuberosity are included in this last group and account for only 1% to 3% of all calcaneus fractures (3,4). Owing to its low incidence, little is known about this injury. Because most of the published literature on avulsion fractures has focused on describing different surgical techniques for treatment (5–8), there is a lack of knowledge about the patterns of injury, anatomic underlying variables, and specific prognostic factors.

The presence of osteoporosis, diabetes, and neuropathy may facilitate the appearance of the fracture (2,4,9). A broader insertion of the Achilles tendon in the posterior tuberosity, which has been seen in about 20% of population in cadaveric studies (10), has also been proposed as an underlying factor for the classically described "beak" fractures (11), and sets the basis for the morphologic classifications of the avulsion fractures of the posterior calcaneal tuberosity (11,12).

The thin soft tissue envelope and poor vascular supply at this area predispose complications after treatment. Increased age, medical comorbidities such as hypothyroidism and vascular peripheral disease, and skin compromise at presentation have also been identified as bad prognosis factors (13). However, the influence of specific characteristics of the fracture such as fragment size and displacement has not been studied. Furthermore, classifications described previously are exclusively based on the morphologic features of the fracture, with no demonstrated prognostic value (13). The primary goals of this study were to determine if fragment size or fracture displacement were associated with higher complications and to develop a new classification system

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with prognostic value for the avulsion fractures of the posterior calcaneal tuberosity. The secondary goal was to describe the demographic characteristics and outcomes of a large series of patients treated in our center.

Patients and Methods

A review was performed at a level I trauma center. Patients with the avulsion fracture of the posterior calcaneal tuberosity treated consecutively from January 2002 to December 2015 were identified and reviewed from the database of the Traumatology and Orthopedic Surgery service. Fractures extending to the articular posterior facet of the calcaneus, such as Essex-Lopresti tongue-type fractures, were excluded, including cases with ipsilateral foot or ankle fractures.

Diagnosis was achieved in the emergency area in all cases. Anamnesis and physical examination were recorded, and radiographs were obtained systematically, with at least 1 lateral view of the injured side. Age, sex, diagnosis of diabetes mellitus, mechanism of injury, open fracture, fragment size (measured as the maximum diameter in millimeters in any radiologic view), and displacement of fracture (measured as the distance in millimeters between the most posterosuperior point of the calcaneal tuberosity and the most posteroinferior point of the fragment in lateral radiographs) were documented from the initial medical history. Fractures were classified during the radiographic review, as proposed by Beavis et al (11), into 3 types: type I, "sleeve fractures," in which a shell of the cortical bone is avulsed; type II, "beak fractures," an oblique fracture line running posteriorly from behind the Bohler angle; and type III, "infrabursal avulsion fractures," from the middle third of the posterior tuberosity. Type of the treatment applied, method of fixation, postoperative American Orthopaedic Foot and Ankle Society (AOFAS) score, and follow-up in months were also registered (14,15).

Main outcomes were appearance of any complication and the need for additional surgery after the initial treatment. The secondary outcomes were bony displacement after treatment and soft tissue complications, including infection, skin necrosis, and wound dehiscence. Bivariate associations between the descriptive variables and outcomes were performed to identify the prognostic variables.

Data were analyzed using the SPSS Statistics, version 20.0 (IBM, Armonk, NY). Qualitative data were represented as percentage, and quantitative data were represented as mean and standard deviation. For categorical variables, statistical significance was determined using the χ^2 test. Continuous variables were examined with the Mann-Whitney U test. p Values $< .05$ were considered statistically significant.

Results

During the study period, 21 patients with an avulsion fracture of the posterior calcaneal tuberosity were identified consecutively. Demographic characteristics are represented in Table 1. Surgical treatment was performed in 17 (81%) patients with open reduction and internal fixation, with cannulated screws being the preferred option in 16 (94.11%) cases, followed by fixation with suture anchors in 1 (5.88%) case.

After the treatment, 15 complications were registered in 13 (61.9%) patients (Table 2). A total of 8 (38.1%) patients needed reoperation after the initial treatment, owing to retro-Achilles bursitis (3 cases), wound complications (3 cases), loss of reduction (3 cases), and pseudoarthrosis (1 case). In 2 patients, wound complications and secondary loss of reduction happened simultaneously and required revision surgery.

Table 1
Global demographic characteristics (N = 21)

Variables			
Age (y)	56.95 (22.1)	Beavis	
Sex		Type I	8 (38.1)
Male	8 (38.1)	Type II	13 (61.9)
Female	13 (61.9)	Fragment size	29.81 (13.53)
Mechanism of injury		Fragment displacement	21.33 (11.81)
Low-energy	15 (71.4)	Treatment	
High-energy	6 (28.6)	Conservative	4 (19)
Diabetic	4 (19)	Surgical	17 (81)
Open fracture	1 (4.8)	AOFAS score	73.83 (26.49)
		Follow-up	57.24 (48.75)

Abbreviation: AOFAS, American Orthopaedic Foot and Ankle Society.
Qualitative data are presented as N (%), and quantitative data are presented as mean (standard deviation).

Table 2
Complications after the initial treatment (n = 13)

Complications	n (%)
Loss of reduction	5 (33.33)
Soft tissue complication	5 (33.33)
Retroaquileal bursitis	3 (20)
Fat embolism	1 (6.66)
Pseudoarthrosis	1 (6.66)
Total	15 (100)

Mean fracture displacement was 25.91 (±9.06) mm when any complication was present versus 7.61 (±7.92) mm when no complication was present ($p = .03$). Mean displacement was 30.65 (±5.19) mm when soft tissues complications appeared versus 14.68 (±10.67) mm when they did not appear ($p = .02$). All patients that presented secondary loss of reduction were females. In the group without secondary loss of reduction, only 8 (50%) were females ($p = .04$). No differences were found between any variable and the need for reoperation (Table 3). The Beavis classification was not related significantly with any primary or secondary outcome. The mean AOFAS score for Beavis type I was 73 (± 24.96) and for Beavis type II was 74.36 (± 28.6) ($p = .96$).

The sample was divided into 2 groups, using fracture displacement of 20 mm as the reference. The groups had a similar number of cases (< 20 mm, n = 10; ≥ 20 mm, n = 11). Descriptive variables were comparable, except the rate of cases treated by surgery (6 [60%] in < 20 mm, 11 [100%] in ≥ 20 mm [$p = .03$]) (Table 4). Complications appeared in 10 (90.91%) patients in the ≥ 20-mm displacement group and in 3 (30%) patients in the < 20-mm group ($p = .008$). Five (45.45%) patients in the ≥ 20-mm displacement group developed soft tissue complications versus 0 in the < 20-mm group ($p = .035$). No differences were observed in the secondary loss of reduction rate, reoperation rate, and mean AOFAS score.

Discussion

The low incidence of the avulsion fractures of the posterior calcaneal tuberosity is the reason why little is known about these fractures. The mechanism and pattern of injury differ from intra-articular calcaneal fractures, but few descriptive series have been published. We hereby present, to our knowledge, the second longest series published about this injury.

Typical presentation of the fracture in our series was a female patient in the sixth decade of life who suffered low-energy trauma. Surgery was often needed, and complication rate was 61.9%, with the secondary loss of reduction and soft tissue compromise being the most frequent. These findings are similar to those registered in the longest series published (13), whereas other authors reported a higher frequency in young males suffering high-energy trauma (12). There is a general trend to describe these fractures as osteoporotic insufficiency fractures (2,3,16). Because they have been usually observed in patients over the sixth decade of life, it is logical to conclude that low bone quality plays a major role. however, they can also occur after a high-energy trauma. Diabetes has also been associated with these fractures and with complications after treatment (16,17). Secondary diabetic neuropathy can cause decreased pain sensation at the heel and, therefore, leave it more susceptible to repeated microtrauma that can facilitate the fracture (3). In our series, the prevalence of diabetes was as high as 19%, which remarks the importance of this pathology in the development of the injury.

Need for the secondary surgery varies in the literature from 20% to 36.3% (13,18), similar to our series (38.1%). Most common causes were retroaquileal bursitis, secondary loss of reduction, and soft tissue complications. It is interesting to remark that only medical comorbidities such as hypothyroidism, peripheral vascular disease, and the presence of > 1 comorbidity have been identified as predictors of the need for the secondary surgery (13). Diabetes, skin compromise, and osteopor

Table 3
Relationship between variables and main and secondary outcomes (N = 21 patients)

Variables	Any Complication		*p* Value	Soft Tissue Complication		*p* Value	Secondary Loss of Reduction		*p* Value	Reoperation		*p* Value
	Yes (n = 13)	No (n = 8)		Yes (n = 5)	No (n = 16)		Yes (n = 5)	No (n = 16)		Yes (n = 8)	No (n = 13)	
Sex			.37			.34			.04			.33
Male	4 (30.8)	4 (50)		1 (20)	7 (43.75)		0	8 (50)		2 (25)	6 (46.9)	
Female	9 (69.2)	4 (50)		4 (80)	9 (56.25)		5 (100)	8 (50)		6 (75)	7 (53.1)	
Age (y)	59.46 (18.17)	52.88 (28.27)	.71	64.8 (17.02)	54.5 (23.39)	.38	68.6 (11.32)	53.31 (23.62)	.24	60.25 (12.33)	54.92 (26.72)	.88
Mechanism			.21			.51			.1			.77
Low-energy	8 (61.5)	7 (87.5)		3 (60)	12 (75)		5 (100)	10 (62.5)		6 (75)	9 (69.2)	
High-energy	5 (38.5)	1 (12.5)		2 (40)	4 (25)		0	6 (37.5)		2 (25)	4 (30.8)	
DM	3 (23.1)	1 (12.5)	.54	2 (40)	2 (12.5)	.17	2 (40)	2 (12.5)	.17	3 (37.5)	1 (7.69)	.09
Beavis			.07			.92			.34			.33
Type I	3 (23.1)	5 (62.5)		2 (40)	6 (37.5)		1 (20)	7 (43.8)		2 (25)	6 (46.1)	
Type II	10 (76.9)	3 (37.5)		3 (60)	10 (62.5)		4 (80)	9 (56.2)		6 (75)	7 (53.8)	
Displacement (mm)	25.91 (9.06)	7.61 (7.92)	.03	30.6 (5.19)	14.68 (10.67)	.02	24.43 (11.52)	19.13 (12.4)	.46	24.93 (10.35)	18.77 (12.89)	.37
Size (mm)	28.93 (14.69)	31.6 (12.2)	.28	23.96 (11.02)	32.4 (14.29)	.21	28.48 (5.28)	30.63 (17.2)	.77	33.1 (14.82)	27 (12.78)	1
Treatment			.09			.21			.95			.54
Conservative	1 (7.7)	3 (37.5)		0	4 (25)		1 (20)	3 (18.8)		1 (12.5)	3 (23.1)	
Surgical	12 (92.3)	5 (62.5)		5 (100)	12 (75)		4 (80)	13 (81.2)		7 (87.5)	10 (76.9)	

Abbreviation: DM, diabetes mellitus.
Qualitative data are presented as N (%), and quantitative data are presented as mean (standard deviation). The *p* values were considered statistically significant if < .05.

osis have been suggested as the risk factors (3), but none of them have been demonstrated. In this work, any variable was significantly associated with the need for the secondary surgery, but there was a trend in diabetic patients.

Table 4
Comparison between groups with < 20 mm and ≥ 20 mm of fracture displacement

Variables	Displacement		*p* Value
	< 20 mm (n = 10)	≥ 20 mm (n = 11)	
Sex			1
Male	4 (40)	4 (36.4)	
Female	6 (60)	7 (63.6)	
Age (y)	52.67 (30.19)	65.67 (15.37)	.57
Mechanism			.63
Low-energy	8 (80)	7 (63.6)	
High-energy	2 (20)	4 (36.4)	
DM	1 (10)	3 (27.3)	.58
Open fracture	0	1 (9)	1
Treatment			.03
Conservative	0	0	
Surgical	6 (60)	11 (100)	
AOFAS score	80.4 (23.35)	58.67 (26.72)	.14
Follow-up	58 (39.67)	56.53 (34.42)	.69
Any complication	3 (30)	10 (90.9)	.008
Soft tissue complication	0	5 (45.4)	.03
Secondary loss of reduction	2 (20)	4 (36.4)	.63
Reoperation	2 (20)	6 (54.5)	.18

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; DM, diabetes mellitus.
Qualitative data are presented as N(%), and quantitative data are presented as mean (standard deviation). The *p* values were considered statistically significant if < .05.

A very large complication rate (61.9%) was registered in our series. Other reports had already stated that these injuries are difficult to treat (19), but there is limited literature regarding the complications and the possible underlying factors. Gitajn et al (13) found that increased age and skin compromise at presentation were related to wound complications and secondary loss of reduction. In our study, fracture displacement was significantly associated with the appearance of any complication in general and soft tissues complications in specific. Furthermore, when displacement was ≥20 mm, complication rate increased from 30% to 90.9%, setting a critical displacement point. None of the previous series had shown the role of fracture displacement on outcomes (12,13,18), which was a key factor in our series.

A few possible explanations exist to explain the role of fracture displacement in the development of complications. Skin compromise secondary to the displacement of the fracture in an area of a poor blood supply, added to the hematoma after the fracture, causes a transient necrosis of the soft tissue around the heel. Second, a more aggressive surgical dissection is needed when the fracture is more displaced. However, no relationship was found between fracture displacement and the secondary loss of fixation. The size of the sample could have contributed to this finding. On the other hand, fragment size was not associated with an increased complication rate.

Females were associated with higher secondary loss of reduction, as 100% of patients with this complication were females, whereas 50% were without it. Although this finding could be biased owing to the sample size, no certain biologic explanation can be given for this difference; thus, surgeons should be aware of it when treating female patients for the avulsion fractures of the posterior calcaneal tuberosity.

The Beavis classification did not show any significant association with complication rate and with any specific complication or outcome; however, a trend was observed, as type II fractures accounted for 76.9% of all fractures that developed any complication ($p = .07$). This finding was

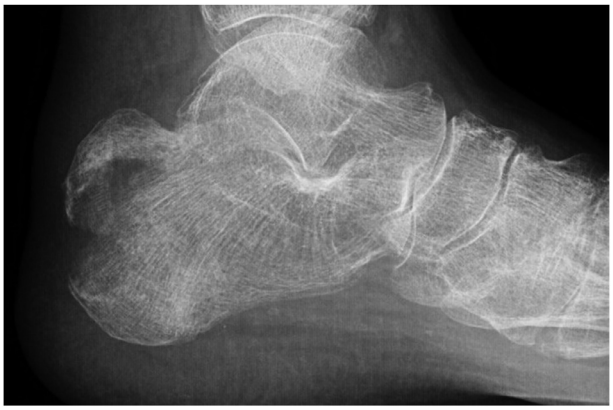

Fig. 1. Lateral calcaneus projection. Posterior calcaneal tuberosity avulsion fracture displaced < 2 cm.

already noticed in the literature (13) and was confirmed in our series. The Beavis classification is a purely morphologic classification that limits to describe fractures based on their shape. It also relates the type of fracture with the type of Achilles insertion in the posterior tuberosity. Beavis types I and II are associated with a broad insertion of Achilles, whereas type III corresponds to the insertion at the middle third of the tuberosity. Recently, Lee et al (12) modified this classification, adding a new subtype and stating that both types III and IV were partial insertional ruptures of the Achilles tendon. A treatment algorithm was developed from these anatomic descriptions, but no prospective data exist to confirm its utility. We hereby demonstrate that fracture displacement, and not morphology, is the variable responsible for the outcomes, because it has shown to be the only fracture-related feature that influences prognosis.

We believe that the classification of fractures must give reliable information about the optimal treatment or, at least, about prognosis. Therefore, we developed a new, easy, and reproductible classification system based on fracture displacement:

1. *Type 1:* Fractures displaced < 2 cm: They have a 30% probability of complication after treatment (Fig. 1).
2. *Type 2:* Fractures displaced ≥ 2 cm: They have a 90% probability of complications, specifically soft tissue complications (Fig. 2).

The present study has several limitations. Despite being, to our knowledge, the second largest series published, the sample size was small, which limited the possibility of obtaining significant differences when analyzing prognostic factors and complications. Second, more surgeons tended to favor internal fixation with cannulated screws, with only 1 using suture anchors and none using suture fixation through bone tunnels or tension-band constructs. This fact might have influenced the high complication rate obtained. On the other hand, less variability in the surgical technique makes our sample more homogeneous.

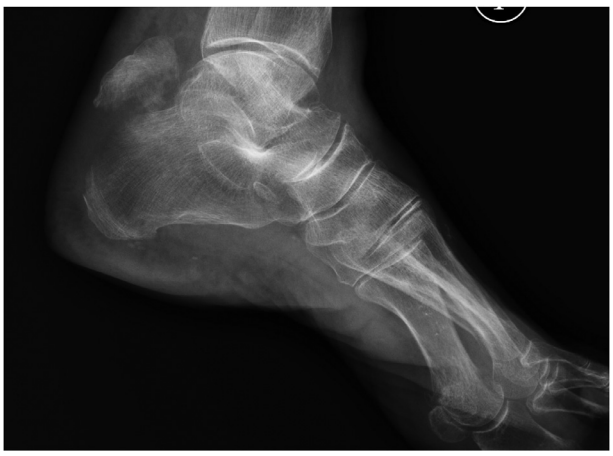

Fig. 2. Lateral calcaneus projection. Posterior calcaneal tuberosity avulsion fracture displaced > 2 cm.

In conclusion, this study contributes to extend the knowledge about the avulsion fractures of the posterior calcaneal tuberosity. They were observed more frequently in females in the sixth decade of life after a low-energy trauma. Twenty percent of the patients were diabetic. Complication rate was 61.9%, with secondary loss of reduction and soft tissue complications being the most common. Secondary surgery was needed in 38.1%. Fracture classification with Beavis system did not show prognostic value. Instead, fracture displacement ≥ 2 cm was related with a significantly higher probability of developing any complication in general and soft tissue complications in specific. A new classification system with prognostic value is described. Larger and prospective series of patients or comprehensive reviews are needed to clearly identify optimal management and prognostic factors of the avulsion fractures of the posterior calcaneal tuberosity.

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