

# The types of talar articular facets and morphometric measurements of the human calcaneus bone on Turkish race

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Received: 3 April 2008 / Published online: 23 September 2008  
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## Abstract

**Introduction** There are three facets over upper side of talocalcaneal joint: anterior talar facet, middle and posterior. Three types of calcaneus that have distinct talar facets were defined as types A, B and C.

**Materials and methods** A total of 221 calcanei (98 right, 123 left), with unknown gender, were dried and evaluated.

**Results** In our study type B calcaneus (58%) was defined as the most common type, and type A calcaneus (39.3%) as the second most common type. By using facet joint differences and bone measurement, we tried to define calcaneus bone.

**Discussion** In many diseases of foot, such as the talocalcaneal arthritis and coalition, intraarticular fractures and congenital dysmorphism, flatfoot, valgus deformities, the size and shape of the bones, the relationships of the talus and calcaneus with each other and other bones of the foot must be considered for the internal and external fixation and surgical procedures. Type B calcaneus was defined as the most common type in Turkish race and these results correlate with the ones which were performed on bones of American, Indian and African people, and it was uncorrelated with the results of the researches performed in Europe.

**Keywords** Calcaneus · Facet · Anatomy · Talus · Human

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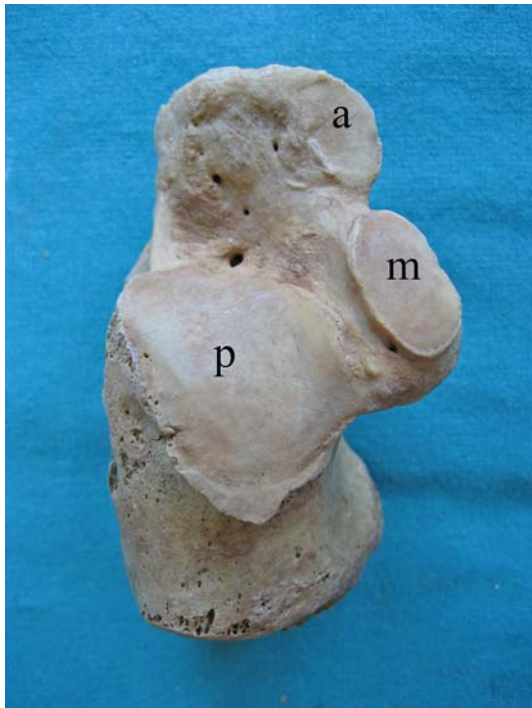
## Introduction

Calcaneus is the biggest and longest among the tarsal bones. It forms talocalcaneal joint with talus. This joint maintains eversion and inversion of foot and named as subtalar joint. There are three facets over upper side of talocalcaneal joint: anterior talar facet, middle and posterior (Fig. 1). Using parameters such as degree of separation, fusion and shape, some researches have described types and preponderance of articular facets. Morphometric values of calcanei are important for the science of anatomy, treatment and diagnosis procedures on orthopedic surgery, kinesiology, physical treatment and rehabilitation sections. The racial and individual differences of the anatomic construction of the calcanei play a key role on static and kinetic dynamic on the foot. During the treatment period of the congenital club foot, talocalcaneal coalition, severe pronation cases, valgus deformities, subtalar instability and development of subtalar implants talus–calcaneus relation should be well defined [1–3, 8, 9, 16, 20, 24, 25, 28]. Especially in calcaneus fractures, in diagnosis and treatment, radiographics of Boehler's angle are used in orthopedic surgery. Preoperatively decreased Boehler's angle is in favor of fracture [5, 7, 11, 15].

By using facet joint differences and bone measurement, we tried to define calcaneus bone at Turkish race.

## Materials and methods

In the anatomy department of Ege University Medicine Faculty, a total of 221 calcanei (98 right, 123 left) dried, without prominent pathology, with unknown gender, were evaluated one by one. Three types of calcaneus that have distinct talar facets as types A, B and C were defined by



**Fig. 1** The calcaneus. *p* facies articularis talaris posterior, *m* facies articularis talaris medius, *a* facies articularis talaris anterior

using Campos and Pellicio's parameters according to the report of Koshy et al. [16]. Type A: On calcaneus, anterior and middle talar facet were observed, forming a joint with the head of talus. Since the degree of separation of these two joint facets was different, Type A was divided into following four subtypes (Fig. 2).

A1: the distance between anterior and middle talar facets was less than 2 mm.

A2: the distance between anterior and middle talar facets was 2–5 mm.

A3: the distance between anterior and middle talar facets was more than 5 mm.

A4: there was only one joint facet, named as anterior talar facet.

**Fig. 2** Types A1, A2, A3, A4 calcaneus



**Fig. 3** Types B1, B2 calcaneus

The A1, A2 and A3 of types have three joint facets while A4 has two.

Type B: There is no separation between anterior and middle facets. There was a common joint facet for talus head. Calcaneus has two joint facets (Fig. 3).

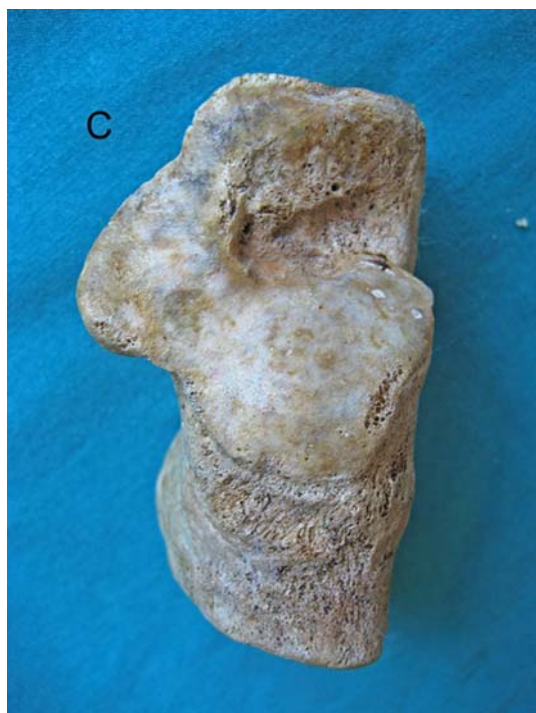
Type B1: the separation between these two joint facets was not completed. The shape of facet joint was constricted (anteromiddle joint facets were constricted).

Type B2: there was no separation between these two joint facets. There was only one wide smooth facet (unconstricted).

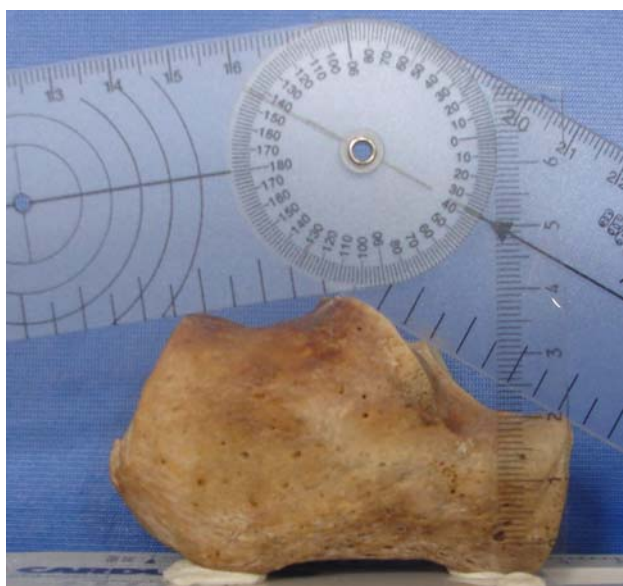
Type C: there was no separation between these three joint facets. There was one joint facet (Fig. 4).

We used following values during calcaneus measurements: maximum anterior–posterior length, maximum transvers diameter, width, depth, length of the groove over the sustentaculum tali, width, depth, length of the calcaneal sulcus.

Calcaneus was fixed on transvers axis, like calcaneus of a man standing. Boehler's angles were measured with a universal goniometry at frontal axis. Boehler's angle stands between two lines, and it is directed towards anterior or posterior (Fig. 5), [7, 15]. These lines are:



**Fig. 4** Type C calcaneus



**Fig. 5** Calcaneus was fixed on transvers axis and Boehler's angles were measured with a universal goniometry at frontal axis

- 1: superior margin of posterior facet to superior margin on anterior process.
- 2: superior margin of posterior facet to superior margin of tuberosity.

The superior margin of posterior facet to floor and the vertical length of calcaneus were measured (Fig. 5).

Measurements were carried out with a digital caliper. The correlation analysis was performed by using Pearson

rank correlation coefficients. SPSS for Windows software was used for data management and statistical analysis. All the results were expressed as mean  $\pm$  SD (standard deviation).

## Results

Based on our morphometric study of articular facets on the superior surface of the 221 calcanei, three distinct calcaneus types could be identified (Table 1).

Type A calcaneus was observed on 87 samples (39.3%, 48 on the left, 39 on the right). 9 (4%, 5 on the left, 4 on the right), 29 (13%, 15 on the left, 14 on the right), 38 (17%, 22 on the left, 16 on the right) and 11 (4.9%, 5 on the left, 6 on the right) were A1, A2, A3, A4 subtypes, respectively. Type B calcaneus was observed on 129 samples (58.3%, 74 on the left, 55 on the right) with the highest frequency. 56 were subtype B1 (25.3%, 33 on the left, 23 on the right) while 73 of them were B2 (33%, 41 on the left, 32 on the right). Type C calcaneus was observed only on five samples (2.2%, 1 on the left, 4 on the right).

The morphometric measurements were carried out using Koshy's parameters and findings were demonstrated with Koshy's findings on Table 2.

In the left and right calcanei, the Boehler angles were found as mean  $30.8^\circ \pm 4.9^\circ$  with a range of  $18^\circ$ – $42^\circ$ , and  $30.09^\circ \pm 5^\circ$  with a range of  $20^\circ$ – $42^\circ$ , respectively. The vertical length of the calcaneus was found as mean  $48.3 \pm 3.7$  mm in left (min–max: 39–58 mm), and  $48.2 \pm 3.2$  mm in right (min–max: 41–55 mm). The change of vertical length is important in the decompression fractures of the calcanei.

In the correlation analysis (Pearson), left Boehler's angle was highly correlated with the left vertical length of the calcaneus ( $r = 0.38$ ) while there was no relation for the right side.

**Table 1** According to anterior, middle and posterior talar facets, there were three types calcaneus: Type A, B, C. In our study type B calcaneus (58%) was defined as the most type (bold)

	Number	%	Left	Right
A1	9	4	5	4
A2	29	13	15	14
A3	38	17	22	16
A4	11	4.9	6	5
<b>B1</b>	56	<b>25</b>	33	23
<b>B2</b>	73	<b>33</b>	41	32
C	5	2.2	1	4
Total	221	100	123	98



**Table 2** The morphometric measurements of the calcaneus. The comparison of our findings with those of the Koshy's

Calcaneus millimeter (mm)	Koshy	Present	
		Right	Left
The anterior–posterior length of the calcaneus	73.6 ± 5.7	77.5 ± 5.7	77.9 ± 5.6
Transvers diameter of the calcaneus	40.8 ± 4.6	48.1 ± 4	46.9 ± 4.4
The width of the groove over the sustentaculum tali	10.8 ± 1.5	6.6 ± 1	7 ± 1.3
The depth of the groove over the sustentaculum tali	02.9 ± 0.6	2 ± 0.5	1.8 ± 0.5
The length of the groove over the sustentaculum tali	20.7 ± 3.2	21.5 ± 2.2	21.2 ± 2.37
The width of the calcaneal sulcus	21 ± 2.4	5.8 ± 1.7	6.5 ± 3.7
The depth of the calcaneal sulcus	03.4 ± 0.9	2.5 ± 0.7	2.6 ± 0.7
The length of the calcaneal sulcus	31.9 ± 3	30 ± 3	30.8 ± 3.2

## Discussion

The joint faces on calcanei which articulate with talus show racial and individual differences. In textbooks, anterior and posterior facets are mentioned separately while the middle one is defined as the continuation of the anterior facet. Although it is necessary to define and appreciate these differences for many science branches to make accurate diagnosis and the treatment, there is no detailed knowledge indicating these differences. It is well known that the treatment choices of the complex foot deformity are osteotomy, anatomic reduction, and relaxation of the soft tissue to obtain a normal-sized, painless and functional foot. It would be helpful to know the pathological and clinical anatomy of the deformed foot so that some structurally based treatment plan could be formulated. In many diseases of foot, such as the talocalcaneal arthritis and coalition, intra-articular fractures and congenital dysmorphology, flatfoot, valgus deformities, the size and shape of the bones, the relationships of the talus and calcaneus with each other and other bones of the foot must be considered for the internal and external fixation and surgical procedures [1, 3, 6, 8, 9, 16–19, 24, 25, 27–29].

Calcaneal lengthening operations are performed in symptomatic valgus deformities in children [21]. Modified calcaneal lengthening osteotomy operation can correct the deformity without hindering the motion of talocalcaneal joint in patients with flexible pes planovalgus. In many operations, osteotomy and graft patching were done between facets of the subtalar joint. The size and the distances between the facets and the dimensions of the calcaneus are important for a successful osteotomy, in using either subtalar implants or grafts [8, 9, 16–18]. Three-dimensional computerized imaging techniques may present facet surfaces of talus and calcaneus. So, in talocalcaneal subluxation, coalition and many dysmorphologies, success rate of diagnosis and treatment will increase and talocalcaneal joint implants and prosthesis may be developed [1, 17, 24].

Campos and Pellicio, examined 176 calcanei in their study, in Spain. They observed A1 in 1 specimen, A2 in

12 specimens, A3 in 14 specimens, A4 in 7 specimens, B1 in 28 specimens, B2 in 24 specimens among 86 right calcanei. They observed A1 in 4 specimens, A2 in 25 specimens, A3 in 14 specimens, A4 in 5 specimens, B1 in 23 specimens, B2 in 19 specimens among 90 left calcanei. Type C was not found [4].

Gupta and colleagues have examined 401 normal Indian calcanei. They have observed type B most commonly (67%) and type C (2%) least commonly. Later, Padmanabhan examined 272 calcanei in Indian race and achieved similar results compared to Gupta's (Table 3), [10, 20, 25].

**Table 3** The comparison of our results with those of the other researchers. For in white race type A calcaneus and in black type B calcaneus has a high ratio (bold)

	Type (%)								
	A	A1	A2	A3	A4	B	B1	B2	C
Bunning and Barnett									
White	<b>67</b>					33			
Black	36					<b>63</b>			
Indians	22					78			0
European	67					33			0
Africans	36					63			1
Gupta									
Indians	31	9	4	13	5	67	28	39	2
Padmanabhan									
Indians	35					65			0
Campos & Pellicio									
Spain	46	3	21	16	6	54	29	25	0
Saadeh									
Egypt		20	6.7	3.4					
Ragab									
Americans	37				12	46			0.2
White	<b>47</b>					33			
Black	23					<b>60</b>			
Present									
Turkish	39.3	4	13	17	5	58	25	33	2.2

The common variations in the talar facets on the calcanei have been described in detail by Bunning and Barnett in British, Nigerian and Indian subjects. They have examined adult and fetal calcanei. Their research pointed out a higher percentage of type A among the Europeans and a higher ratio of type B among the Africans and Indians. They have observed a minimal percentage of type C among the Africans, and none among the Indians and Europeans. In addition, among the European women they have observed type A with a higher ratio, and among the African and Indian women type B has been observed in a higher ratio. Type A calcanei has been observed with rates of 67% for white people, 36% for black people and type B calcaneus has been observed in 33% for white people, 63% for black people (Table 3), [3].

Saadeh and colleagues have examined 300 calcaneus in Egypt. They have observed type B as the most common type and type C as the least common type. They have observed type A1; 20%, type A2; 6.7%, type A3; 3.4% [23]. According to Ragab et al.'s research results, the classification of the calcaneus was: type A 37% (A1; 12%, A4; 6%), type B 46%, type C 0.2%. For white people they have defined type A with a rate of 47%, and type B with a rate of 33% calcaneus, while for black people rates were defined as: type A 23% and type B calcaneus 60% [22]. The findings of Ragab was similar with Bunning–Barnett's. For white people type A calcaneus and for black people type B calcaneus was observed two times more than the others. Based on the measurements performed on calcanei, Koshy and his team created a morphological map of the bone. Their findings may be seen in Table 2 (Table 3), [16].

In our study type B calcaneus (58%) was defined as the most common type, and type A calcaneus (39.3%) as the second. Campos and Pellico defined that type A calcaneus (46.59%) had the highest ratio and type B calcaneus (39.77%) was the second most common type, while they have not observed any type C calcaneus [4]. In Indians Padmanabhan defined type B calcaneus as the most common type [20]. Bunning and Barnett observed that type A calcaneus was common two times more than type B calcaneus, and that made sense as Europeans are white people type A calcaneus was the most seen type, where in Indians and Africans type B calcaneus was the most frequent one [3]. Ragab's findings were also similar with Bunning–Barnett's, as for white people type A calcaneus (47%) and for black people type B calcaneus (60%) had a higher ratio [22]. Among Egyptians (Egypt is an African country) type B calcaneus was defined as the most common type according to Saadeh's study results [23]. All other researches pointed out that type C was the least common type among all the others (Table 3).

Type B calcaneus was defined as the most common type in Turkish race and these results correlate with the ones

which was performed for Americans, Indians and Africans and it was uncorrelated with the results of the researches performed in Europe. In the light of these data we believe it is necessary to maintain researches with an extended content (Table 3).

The differences were often observed in the anterior and middle facet surfaces in studies performed with scanning techniques [1]. In the literature treatment of calcaneus fracture has a wide variety. However, treatment of open calcaneal fractures has not been discussed in detail. Various treatment alternatives have been suggested including external fixator, primary subtalar distraction arthrodesis, and partial calcaneotomy according to the type of fracture. We are suggesting that the detailed calcaneus anatomy shall facilitate the alternatives of the treatment procedures [26].

There is no consensus on which fracture classification to be used at calcaneus fractures while deciding about surgical treatment options. Boehler's angle changes especially at decompression fractures. Having the same Boehler's angle postoperatively with comparison of pre- and postoperative Boehler angles demonstrates surgical success. Postoperative vertical length of calcaneus may be a supportive criterion at calcaneus fractures [5, 7, 11–13, 15, 26].

The mean Boehler's angle in the Saudi population was 31.21° and is not related to age, gender, or side of body according to Khoshhal's research. This research supported our results [14].

Kalenderer et al. saw that the Boehler angles in congenital clubfoot are similar compared to the normal side. The mean Boehler's angle was 35.2° in the Kalenderer's patients [12].

Kankare measured mean Boehler angles in patients who have taken operative treatment of displaced intra-articular fractures of calcaneus. The postoperative Boehler's angle had a statistically significant effect on the results. He emphasized that a good anatomic reduction requires a good anatomic knowledge and assessment [13].

Nevertheless, there is an evident deficiency in data about articles subjected to the Boehler's angle in a definite population or race in the current literature. This could be the possible reason of defined wide range (20–40°) of this angle. But postoperative angle measurements would be more valuable if mean Boehler angles of populations were determined before [7, 11].

Independent from the type of treatment, main aims are restoration of congruency of the facet of the subtalar joint, restoration of the height of the calcaneus, reduction of the width of the calcaneus [26].

Today with the aid of the improvement of the technology there has been a great development of the subtalar implants, the flaps and prothesis for the foot. Detailed anatomic information will be baseline for advanced treatment procedures [1, 6, 8, 19, 22, 24, 25, 28, 29].

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