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STUDY OF THE MORPHOLOGIC AND MORPHOMETRIC PATTERNS OF TALAR ARTICULAR FACETS ON DRY ADULT CALCANEAL BONES IN SOUTH-EASTERN NIGERIAN POPULATION

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RESUMEN

Introducción: El calcáneo es el hueso tarsiano más largo y más largo del pie y forma la prominencia del talón. El tercio medio de la superficie superior del calcáneo proporciona una faceta articular para el hueso del talud. Objetivo: El estudio busca observar las variaciones en la morfología y morfometría de las facetas articulares del talar en la superficie superior de huesos calcáneos secos de humanos adultos en la población noreste de Sudeste. Material y métodos: El estudio se llevó a cabo en 220 calcáneos secos no patológicos adultos de sexo desconocido de bancos de huesos de varios colegios médicos en el sureste de Nigeria. Resultados: El patrón 1 fue el más frecuente en el presente estudio (55,4%). La forma ovalada era común en las facetas articulares anterior y media del talar (52,86% y 64,39%), oval y convexa en la faceta posterior (70%) y la forma alargada era común entre las facetas fusionadas anterior y media (63,12%) Con ovalo alargado común en el subtipo 2 (27,87%) y constreñido alargado común en el subtipo 1 (35,25%). La longitud del calcáneo se registró con una media ± DP de 7,10 ± 0,70 cm (lado izquierdo) y 7,01 ± 0,72 cm (lado derecho) y la anchura se registró a 2,77 ± 0,38 cm (lado izquierdo) y 2,77 ± 0,37 Cm (lado derecho). La distancia entre las facetas anterior y media fueron de media ± DP de 0,50 ± 0,15cm (lado izquierdo) y 0,48 ± 0,15cm (lado derecho), las facetas Posterior y Media a 0,59 ± 0,20cm (lado izquierdo) y 0,56 ± 0,17cm (Lado derecho) y entre las facetas anterior y posterior a 1,43 ± 0,27 cm (lado izquierdo) y 1,42 ± 0,29 cm (lado derecho). Conclusión: Un buen conocimiento del patrón y forma de la faceta del calcáneo ayudaría a mejores opciones de tratamiento y manejo de las fracturas del calcáneo. También requiere una modificación de las técnicas quirúrgicas occidentales para adaptarse al escenario nigeriano para la osteotomía calcánea.

Palabras clave: *Calcáneos, facetas articulares de Talar, patrón, forma, población nigeriana del sudeste*

ABSTRACT

Background**:** Calcaneum is the largest and longest tarsal bone in the foot and forms the prominence of the heel. Objective**:** The aim of the study was to observe the variations in the morphology and morphometry of the talar articular facets on the superior surface of human calcanei in South-Eastern Nigeria. Materials and Methods**:** The study was carried out on 220 adult non-pathological dry calcanei of unknown sex from bone banks of various medical colleges in South-Eastern Nigeria. Each calcaneum was examined for various patterns of articulating facets. Results**:** Pattern 1 was 55.4% of the studied population, Pattern II 7.7%, Pattern III 12.7% and Pattern IV 24%. The oval shape was 52.86% and 64.39% in the anterior and middle talar articular facets respectively, oval and convex was 70%in the posterior facet and the elongated shape was 63.12% in the fused anterior and middle facet with elongated oval 27.87% in subtype 2 and elongated constricted 35.25% in subtype 1.The length of the calcanei was recorded at a mean±SD of 7.10±0.70cm (left side) and7.01±0.72cm (right side).The width was 2.77±0.38cm (left side) and2.77±0.37cm (right side). The distance between the anterior and middle facets was 0.50±0.15cm (left side) and 0.48±0.15cm (right side); the posterior and middle facets at 0.59±0.20cm (left side) and 0.56±0.17cm (right side) and that between the anterior and posterior facets at 1.43±0.27cm (left side) and 1.42±0.29cm (right side). Conclusion: A good knowledge of the calcaneal facet pattern and shape may be useful in forensic medicine.

Key words: *Calcaneum, Talar articular facets, Pattern, Shape, South-Eastern Nigerian population*

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INTRODUCTION

Calcaneum or os calcis is the largest and longest tarsal bone in the foot and forms the prominence of the heel (Snell, 1993). It is located postero-inferior to the talus, providing support to the ankle joint (Ellis, 2006; Uygur et al., 2009). It measures about 8.50cm in length and about 3.50cm at its widest point (DuVries, 1959).The middle third of the superior surface of the calcaneus carries the posterior talar facet (oval and convex antero-posteriorly), for articulation with the body of the talus. This talar facet may be divided in about half the cases by a non-articular zone creating middle (posteromedial portion) and anterior (antero-lateral portion) talar facets, the incidence of which varies with race and sex (Mini et al., 2012).The posteromedial portion lies almost in the transverse plane making an angle of approximately 40º with the anterolateral portion.

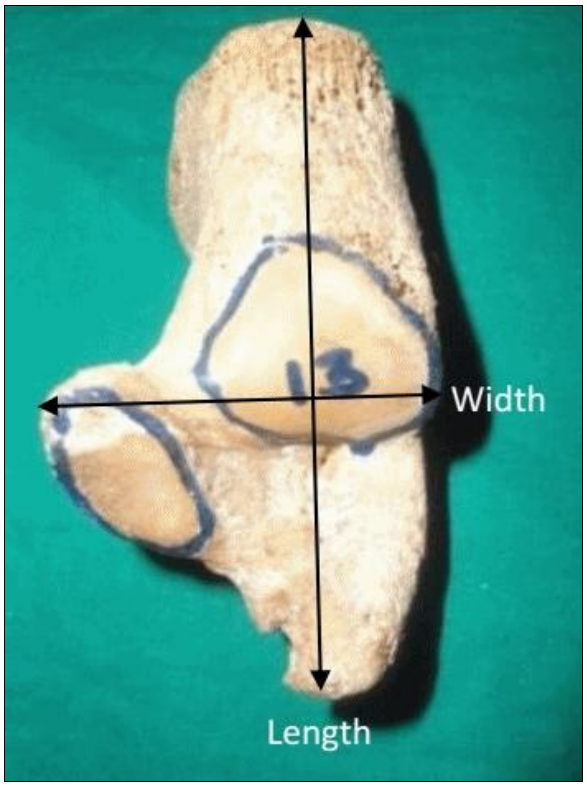

Figure 1.- Showing the measurements of length and width of the calcaneus

The talar articular facets on calcaneus show marked and very frequent variations (Rohin et al., 2013). Variations of the articular facets in the superior surface of the calcaneus for the talus may be a consequence of external factors or of anthropological factors such as the angle of talar torsion or the angle of declination of the talus in the adult and the angle between the longitudinal axis of the talar body and the talar neck (Campos et al., 1989). Morphological variability of the calcaneal facets could also result from differences in gait or other habits influencing these articular areas post-natally or it could be indicative of genetically determined variation (Bunning and Barnett, 1965).

The morphology of the articular facets of calcanei has been a subject of interest toanatomists hoping to help the Orthopaedic surgeons in diagnosis and treatment of deformities and injuries in the region of foot.(Rohin et al., 2013, Chavan et al., 2014, Jagdev et al., 2015). The present study however, was a sincere effort to analyze the morphology and morphometric patterns of talar articular facets of South-Eastern Nigerians as there are very scanty studies reported.

MATERIALS AND METHOD

Two hundred and twenty (220) dry adult human calcanei (111 left and 109 right) of unknown sex and age from osteology units of different medical colleges in South-Eastern Nigeria were used for the study.

Inclusion Criteria

In the selection of the calcanei, the following criteria were taken into consideration:

- The bones were adult calcanei of both sexes.
- The calcanei were complete in all respects so as to give the correct measurements.
- The calcanei were non- pathological

Exclusion Criteria

- Pathological calcanei
- Calcanei with broken off parts (incomplete calcanei)

Method of Data Collection

The patterns of the talar articular facets of calcanei and the shapes of the different articular facets were examined and the calcanei sorted out according to the type of pattern present. A marker was used to encircle the facetal margins to clearly mark the separation between the facets, and the distance between them measured with a sliding Vernier caliper of 0.02cm accuracy. The length and width of calcanei of right side and left side were also measured and a 16.0 mega pixel Casio digital camera was used to take photographs of different patterns of talar articular facets of the calcanei.

All measurements were done three times and the average taken.

Measurement Parameters

- Length of calcaneus (cm)
- Width of calcaneus (cm)
- Interfacetal distances (cm)

Measurement of calcaneal length: The total length of the calcaneum was measured between anterior points of upper parts of the articular facets or facet for cuboid to the posterior rough bony part for the attachment of the tendo-calcaneus with a sliding venier caliper of 0.02 accuracy in centimeter (cm) scale as illustrated in figure 1.

Measurement of the calcaneal width: The width of the calcaneum was measured from the medial calcaneal tuberosity to the lateral calcaneal tuberosity with a sliding caliper in cm scale as illustrated in figure 1.

Measurement of interfacetal distances: When the articular facets are separate entities, the distance between them was measured with vernier caliper in cm scale. The posterior most part of the anterior facet was taken as the anterior point and the anterior most part of the posterior facet was taken as the posterior point. These include

- Distance between anterior and middle facets
- Distance between middle and posterior facet
- Distance between anterior and posterior facets.

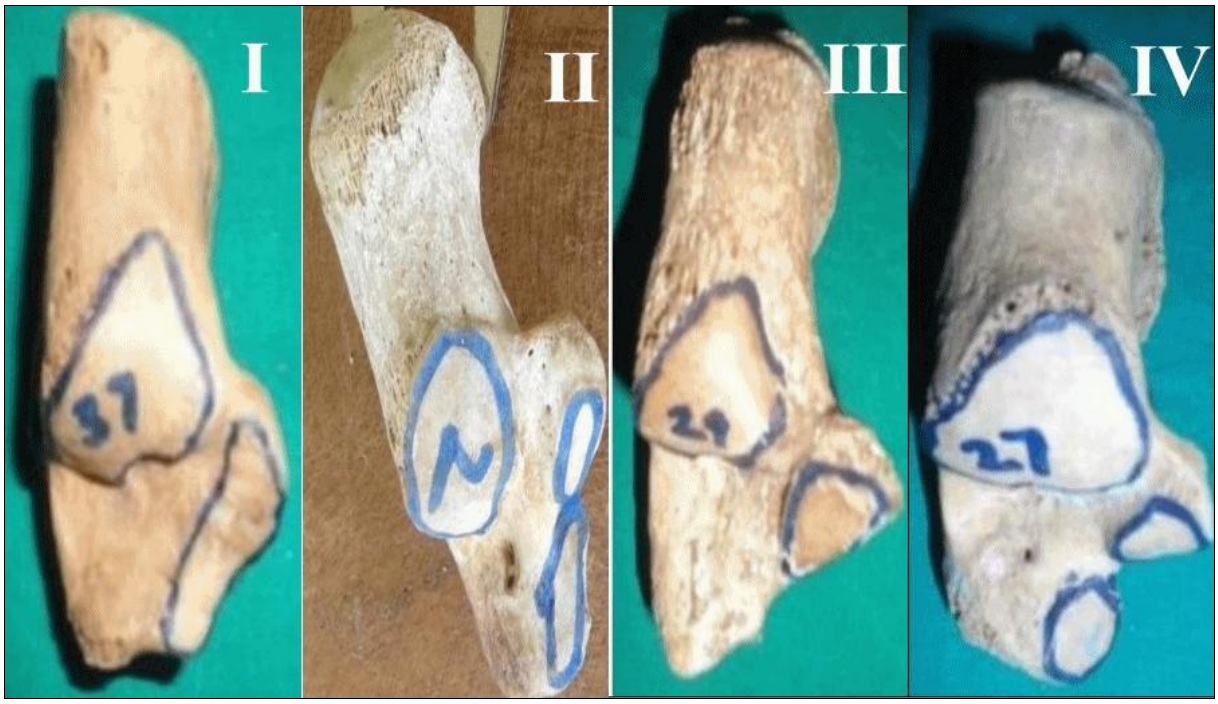

Figure 2.- Showing Patterns I, II, II, IV on the right calcaneus

Classification of calcaneal articular facets

The patterns of talar articular facets were observed and classified according to the grouping methods of Bunning and Barnett (1963, 1965), and Anjaneyulu et al (2014) classific-ations.

I. **Pattern I**: Fused anterior and middle articular facets with a separate posterior facet as shown in figure 2, which corresponds to group C of Anjaneyulu et al (2015) classification. This is further divided into two sub types:
   - **Pattern I (a)** which has constricted facet.
   - **PatternI (b)** which has no constricted facet.

II. **Pattern II:** Three facets are seen on the superior surface of the calcaneus with anterior and middle facets incompletely separated from each other.as shown in figure 2

III. **Pattern III:** Absence of anterior articular facet as shown in figure 2corresponding to findings of Jha et al (1972), and Anjaneyulu (2015).

IV. **Pattern IV:** Anterior, middle and posterior facets present i.e. presence of the three articular facets as shown in figure 2. Based

on the degree of separation between the anterior and middle facets, it is divided into three subtypes

- **Pattern IV (a):** separation between the facets is less than 0.35cm
- **Pattern IV (b):** separation between the facets is between 0.35cm-0.5cm
- **Pattern IV (c):** separation between the facets is greater than 0.5cm

The calcanei were also grouped and classified based on the shape of the talar articular surface.

Statistical Analysis

The data collected was analyzed using Statistical Package for Social Sciences (SPSS) Version 20.0. The frequency of distribution, mean and standard deviation of the different calcaneal measurements were derived. An independent t-test was used to determine the differences in the measurement of length and width of right and left calcaneus at (p>0.05) level of significance.

RESULTS

In Table 1 showing the different morphometric patterns of the talar articular surfaces on right and left sides of the adult dry calcaneus, pattern 1 showed the greatest prevalence in both left (51.4%) and right sides (59.6%), followed by pattern 4 in left (27.0%) and right (21.1%) sides while Pattern 5 was not found in the present study.

Pattern	Left Side *n*(%)*	Right side *n* (%)*	Total
I	57 (51.4)	65 (59.6)	122
II	09 (8.1)	08 (7.3)	17
III	15 (13.5)	13 (11.9)	28
IV	30 (27.0)	23 (21.1)	53
V	00	00	00
Total	**111(100)**	**109(100)**	**220**

Table 1 - Different morphometric patterns of the talar articular surfaces on right and left sides of the adult dry calcaneus. n*: Total percentage of the different patterns.

From table 2 showing the subtypes of the patterns I and IV on the left and right sides, it is evident that pattern 1 subtype II is dominant on the left side (36.8%) while pattern 1, subtype I is dominant on the right side. The incidence of pattern IV subtype C is higher on the left side (17.2%) while the incidence of pattern IV subtype B is higher on the right side (11.4%).

Pattern	Subtype	Left Side *n (%)*	Right Side *n (%)*	Total
I	I	25 (28.7)	39 (44.3)	**64**
I	II	32 (36.8)	26 (29.5)	**58**
IV	A	05 (5.8)	5 (5.7)	**10**
IV	B	10 (11.5)	10 (11.4)	**20**
IV	C	15 (17.2)	8 (9.1)	**23**
Total		**87 (100)**	**88 (100)**	**175**

Table 2 - Subtypes of the patterns 1 and 4 on the left and right sides. n*: Total percentage of the different patterns.

The oval shape was the most common shape of the middle articular facet, in all patterns of talar articular facet with an incidence of 64.39% and the least common shape was irregular with an incidence of 3.06%.The oval and convex was the most common shape of posterior talar articular facet with an incidence of 70% while the least common shape was irregular and convex with an incidence of 30% in 66 cases. The oval shape was the most common shape of the anterior talar articular facet with an incidence of 52.86%, while the least common shape of the anterior talar articular facets is irregular found only on the left calcaneus with an incidence of 1.43%.The most common shape of the fused anterior and middle facets as seen only in pattern I is elongated shape, with elongated oval more common in subtype II and elongated constricted common in subtype I with an incidence of 27.89% and 35.25% respectively.

Independent sample t-test of the calcaneal measurements as recorded in table 3 showed that there was no significant difference (p>0.05) in the calcaneal measurements between the left and right sides.

DISCUSSION

The racial and sexual variations in the morphology of talar articular facets of human calcanei is well documented by earlier

researchers (Garg et al., 2013), four different pattern types as described by Saadeh et al (2000), Williams et al (2000) and Madhavi and Antonisamy (2001).Three different types were described by Campos and Pellico (1989), Bunning and Barnett (1965), and Drayer-Verhagen (1993). Two facet configurations were documented by Testut (1986), Laidlaw (1904), Sharrafian (1983), and Padmanabhan (1986). Although a five pattern grouping system was adopted in this study, four different patterns were observed and recorded.

Measurement	Left Side	Right Side	P-Value
Length	7.10±0.70	7.01±0.72	0.376
Width	2.77±0.38	2.77±0.37	0.932
Anterior-Middle	0.50±0.15	0.48±0.15	0.581
Posterior-Middle	0.59±0.20	0.56±0.17	0.279
Anterior-Posterior	1.43±0.27	1.42±0.29	0.873

Table 3 - Calcaneal Measurements. Mean±SD of the measured parameters of the calcanei bones (left and right side).

In this study (table 3), the length of the calcanei was found to be about 7.01±0.72cm on the right side and 7.10±0.70cm on the left side while the width of the calcanei was about 2.77±0.38cm on the left side and 2.77±0.37cm on the right side which is not consistent with the findings of DuVries (1959) who gave the measurement of the calcaneal length to be about 8.50cm and the width about 3.50cm and the findings of Chavan et al.(2014) who reported the calcaneal length to be 8.8cm on the right side and 9.0cm on the left side. This concurs with the consensus that the talar articular facets of calcanei may vary racially (Nagar et al., 2012; Mini et al., 2012; Rohin et al., 2013). The independent T-test done in this present research at the level of p> 0.05 significance shows no significant difference in both the length and width of the calcaneus of left and right sides.

In the present study, the middle talar facet was present as a separate facet on the superior surface of sustentaculum tali in 98 cases; out of which 28 has absence of anterior articular facet. In 54.45%, it was fused with the anterior facet while in 7.73%; the middle facet was incompletely separated from the anterior facet. The most common shape of the middle facet was oval in all patterns of talar articular facets with an incidence of 64.39% (31.68% right and 32.71% on left calcanei). The middle facet was pear shaped in 6.12 % (3.06 % on both sides), triangular in 4.08% (1.02% on the right, and 3.06% on the left), round in 14.28% (9.18% on the right and 5.10% on the left), elongated in 8.16% (6.12% on the right and 2.04% on the left) and the least common shape were irregular with an incidence of 3.06% (2.04% right and 1.02% left). These findings are inconsistent with the works of Jagdev et al (2015) who found oval to be the most common shape of the middle articular facets in 19.5% cases, but found the least common shape to be oval irregular with an incidence of 0.5%. The most common shape of the posterior facet was oval and convex in 70% (33.64% on the right and 36.36% on the left calcanei). This is consistent with the works of Williams et al (2000) but is inconsistent with that of Jagdev et al (2015) where the most common shape was described as irregular and convex. In the present study, the shape irregular and convex was less frequent in 30% (15.91% right and 14.09% left). The anterior facet is present as a separate entity in 31.82% (7.73% belongs to pattern II and 24.10% belongs to pattern IV). The most common shape of the anterior facet is oval present in 52.86% (28.57% on the left and 24.29% on the right). The anterior facet was triangular in 12.85% (6.99% left and 5.71% right), round in 6.36% and elongated in 3.64%. The least common shape of the anterior talar articular facet found in this present study was irregular shaped found with an incidence of 0.45% only on the left calcanei. These findings are inconsistent with the works of Jagdev et al (2015) who found the most common shape of the anterior facet to be oval in 20.5% cases and the least common shape to be pear and triangular in

0.5% cases respectively. This suggests a racial and genetic variation of the articular facets.
The middle and anterior talar facets were fused in 55.45%. The most common shape of the fused facets was elongated with elongated oval more common in subtype II with an incidence of 27.87% (16.39% on the left calcanei and 11.48% on the right calcanei) and elongated constricted more common in subtype I with an incidence of 35.25% (21.31% right and 13.94% left). Oval shape was found only in subtype II with an incidence of 14.75% (6.56% left and 8.19% right) and the least common shape of the fused pattern was curved hockey stick shape with an incidence of 4.10% on the left and 5.74% on the right calcaneus found only in subtype I.

STUDY	YEAR	COUNTRY	n*	PATTERN				
				I (%)	II(%)	III(%)	IV(%)	V(%)
Burning & Barnett	1965	Britain	194	33	__	__	67	__
	1965	Veddah	10	60	__	__	__	40
	1965	Indian	78	78	__	__	22	__
	1965	Nigeria	492	63	__	__	36	1
Campos & Pellico	1989	Spain	176	53.41	__	6.82	39.77	__
Saddeh et al	2000	Egypt	300	63	__	4.7	30.3	2
Barbaix et al	2000	Belgium	134	25	__	11	64	__
Uygur et al	2009	Turkish race	221	58.37	__	4.98	34.39	2.2
Wajid and sarah	2010	Pakistani	350	62.9	__	__	28.6	8.6
Schweta et al	2013	West India	205	64.88	__	4.39	28.78	1.95
Rohin et al	2013	India	310	72.26	__	1.3	24.52	1.6
Anjaneyulu et al	2014	India	100	62	__	5	31	2
Chavan et al	2014	India	60	68.33	__	6.66	25	__
Jagdev et al	2015	India	200	72.5	__	1.5	30	0.5
Gindha et al	2015	North India	325	69.53		0.31	29.85	0.62
Present study	2015	Southern Nigeria	220	55.45	7.72	12.73	24.09	__

Table 4 - Comparison of present study with previous studies. n* total number of calcanei bones studied

The number and arrangement of the articular facets on the superior surface of the calcaneus designated to carry the head of the talus varies from each other as described variously by different authors (Burning and Barnett, 1965; Rohin et al., 2013; Anjaneyulu et al., 2014;

Chavan et al., 2014; Jagdev et al., 2015). Pattern I was found to be the most common in the present research (Table 4). This is consistent with the works of Bunning and Barnett (1965) and Sadeeh et al (2000) who worked on Africans (Nigeria and Egypt). Pattern II although observed at a low incidence of 7.72% (17 cases) in this study was notre corded in previous studies (Burning and Barnett, 1965; Rohin et al., 2013; Anjaneyulu et al., 2014; Chavan et al., 2014; Jagdev et al., 2015). Pattern III was found with an incidence of 28 (12.73%) in the present study. Egyptian studies (Sadeeh et al., 2000) reported this pattern at a low incidence of 4.7% but Bunning and Barnett (1965) did not record to have observed this pattern in their Nigerian study. Pattern IV was found with an incidence of 53 (24.0%) in present study, 36% was reported in the works of Bunning and Barnett (1965), and 30.3% was reported in the works of Sadeeh et al (2000). Pattern V reported by Bunning and Barnett (1965), Sadeeh et al. (2000), Anjaneyulu et al. (2014), Jagdev et al. (2015), Gindha et al. (2015) was not observed in this study.Pattern I was also found to be dominant in India (Burning and Barnett, 1965; Jagdev et al., 2015; Gindha et al., 2015), Pakistani (Wajid and Sarah, 2010), Egyptian (Saddeh et al., 2000), Spanish (Campos and Pelllico, 1989) and Turkish (Uygur et al., 2009) race studies, whereas in European studies (Burning and Barnett, 1965; Barbaix et al., 2000), pattern IV was found to be dominant. This findings suggests that the variations in the morphology of the calcaneus maybe due to racial and genetic factors.

In the present study, pattern I was found to be 59.6% in the right calcanei and 51.4% in the left calcanei Table 1). Though most authors Chavan et al., 2014; Jagdev et al., 2015; Gindha et al., 2015) did not report the statistical significance of the difference between the two sides, it could be observed from their tables that pattern I is dominant in the right side when compared to the left. These differences can be attributed to the following possible reasons. Right lower limb is the initiator of any attempt at the locomotion; hence, the skeletal elements of the right foot have to share the maximum load of forces while inertia is being broken to gain momentum. Right lower limb share proportionately more weight bearing time than left limb and this affects the facetal development on the talus and calcaneus (Chavan et al.,2014).

Incidence of the different subtypes of pattern I and pattern IV also varies between right and left calcanei. In the present study (table 2), pattern I, subtype I (44.3%) were dominant in the right calcanei while subtype II (36.8%) were dominant in left calcanei. This was not in absolute concord with previous works. The findings of Jagdev et al (2015) and Gindha et al (2015) shows dominance of subtype II on the right calcanei. Jagdev et al (2015) found subtype I (51.4%) to be dominant on the left calcanei, however the works of Gindha et al (2015) was in consistent with the findings of the present study on the left calcanei (20.3%).

Study	**Year**	**Country**	**n* (%)**	**Pattern 1 Subtypes**		**n* (%)**	**Pattern 4 Subtypes**		
				I (%)	**II (%)**		**A (%)**	**B (%)**	**C (%)**
Campus & Pellico	1989	Spain	54	29	25	42	5	21	16
Sharada	2012	South India	67	50.3	16.6	28.6	13.66	9.66	3
Anjaneyulu *et al*	2014	Northeast India	62	43	19	31	10	11	5
Present study	2015	Southern Nigeria	55.45	29.09	23.63	24.09	4.54	9.09	10.45

Table 5 - Comparison of the incidence of the subtypes with other studies. n*: Total percentage of the different patterns.

Pattern IV which was the second most common pattern in the present study (table 2) was also subdivided into three according to the degree of separation between the anterior and middle facets. Subtype B was found to be dominant on the right calcanei (11.4%) while subtype C was dominant (17.2) in the left calcanei. Comparing with available literature (table 5), the findings of this study on the right calcanei is consistent with the work of Jagdev et al (2015) who gave the figure as 58% but varies with the findings of Gindha et al (2015) who found subtype A to be dominant on both right and left calcanei of North Indian population with an incidence of 8.62% and 12% respectively. Jagdev et al. (2015) found pattern IV, subtype B to be dominant on the left calcanei with an incidence of 58.6%.

From table 5, it can be deduced that the incidence of the different subtypes of the articular facet for the head of talus varies with race, area and population of study. In the present study, pattern I subtype I and pattern IV, subtype C was dominant with an incidence of 29.09% and 10.45% respectively. Pattern I subtype I and pattern IV subtype B is dominant in Spanish population with an incidence of 29% and 21% respectively from the findings of Campos and Pellico (1989).

When the articular facets were separate entities, the distance between them were measured (see table 3), and no significant difference was observed between the left and right calcaneus ($p>0.05$). The distance between the anterior and posterior facets ranges from 1cm to about 2cm on the left and about 0.98cm to about 2.08cm on the right with a mean distance of about 1.43±0.27cm on the left side and 1.42±0.29cm on the right. The distance between the anterior and middle facets ranges from 0.28cm to about 0.86cm on the right and about 0.2cm to about 0.80cm on the left with a mean distance of about 0.50±0.15cm on the left and 0.48±0.15cm on the right calcaneus. The distance between the posterior and middle facet ranges from 0.3cm to 1.15cm on the left calcanei and about 0.23cm to 1.14cm on the right calcanei with a mean distance of about 0.59±0.20cm on the left and about 0.56±0.17cm on the right calcanei. However, comparative studies are not available for these findings.

The talar articular facets of subtalar joint on calcanei show racial and individual differences. There is a dominance of pattern I calcanei in study population (South Eastern Nigeria) and there appears to be a difference between right and left side talar facets on calcanei bones. The results of this study underline the importance of talar articular facets in determination of race and regional affiliation of an individual. A good knowledge of the calcaneal facet pattern and shape may be useful in forensic medicine.

Conflict of Interest
There was no conflict of interest.

Funding
This research was self-sponsored/funded.

Ethical Approval
The ethical approval for this research was obtained from the Ethical Committee, Faculty of Basic Medical Sciences, College of Health Sciences, Nnamdi Azikiwe University.

Informed Consent
A written consent was sought from the heads of department of Anatomy in different medical colleges in South Eastern Nigeria before access be granted that study be done with the materials in their osteology units

Contributions
UU – Participated in the design of the work and in acquisition, analysis and interpretation of data. Involved in drafting and revising the work critically for important intellectual content. Also participated in the approval of the version to be published.

IFO–Participated in the design of the work and in collection, analysis and interpretation of data. Involved in drafting and revising the work critically for important intellectual content. Also participated in the approval of the final version to be published.

CO- Participated in the conception of the work and in the collection, analysis and interpretation of data. Involved in drafting and revising the work critically for important intellectual content. Participated in the approval of the final version to be published.

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