

ORIGINAL ARTICLE

MORPHOLOGY OF TALAR ARTICULAR FACETS OF CALCANEUS AND ITS CLINICAL IMPLICATIONS

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Introduction: The middle third of the superior surface of calcaneus carries the posterior talar facet, oval and convex antero-posteriorly, for articulation with body of talus. Morphology of the facies articularis talaris of calcaneus plays an important role in statics and dynamics of the foot. This study was undertaken to introduce quantitative parameters in description of talar articular facets of calcaneus. **Methods:** Material for the study comprised of 200 dry (100 right, and 100 left) adult calcanei of unknown age and sex. They were obtained by maceration from cadavers in the Department of Anatomy, Government Medical College, Amritsar, India. Each calcaneum was examined for various patterns of articulating facets for talus. The data were compared with earlier studies. **Results:** Type I calcanei were most common (72.5%). Type II calcanei were 25.5%. Sub-type A was found in 10.5% cases, and Sub-type B were found in 15 cases. Sub-type C was not found in the present study. Type III calcanei was 1.5%, and Type IV were 0.5%. **Conclusion:** Configurations of articular facets influence sub-talar joint stability. Joints with two-facet configuration are comparatively more stable. This fact necessitates modifications of the surgical techniques for performing calcaneal osteotomy.

Keywords: Calcaneum, Articular facets, Pattern, Variation, Subtalar joint

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INTRODUCTION

The calcaneus or *os calcis* is largest of the seven tarsal bones of the foot and forms the prominence of the heel.¹ It measures about 3.5 inch in length and about 1.5 inch at its widest point.² The middle third of the superior surface of the calcaneus carries the posterior talar facet, oval and convex anteroposteriorly, for articulation with the body of the talus. The posterior calcaneal facet can be divided into two portions, an anterolateral portion and a posteromedial portion. This facet articulates with the head of the talus and may be divided in about half the cases by a non-articular zone creating middle and anterior talar facets the incidence of which varies with race and sex.³

The posteromedial portion lies almost in the transverse plane making an angle of approximately 40° with the anterolateral portion. In case of facies articularis talaris posterior, the stress increases to the centre of the articular surface.⁴

Distal (anterior) to the posterior articular facet a rough depression narrows into a groove on the medial side, the sulcus calcanei, which complete the sinus tarsi with the talus. Anterior third is partly articular. Distal and medial to the sulcus calcanei an elongated articular area covers the sustentaculum tali. This facet is often divided by a non-articular interval at the anterior limit of the sustentaculum tali, forming middle and anterior talar facets, the incidence of which varies with sex and race.

The talar articular facets on calcaneus show marked and very frequent variations. 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.⁵

Morphological variability of the calcaneal facets could result from differences in gait or other habits influencing these articular areas post-natally or it could be indicative of genetically determined variations.⁶ While a consensus exists in the anatomic literature about the morphology of the posterior facet, there are divergent descriptions of the anterior facet⁷, their incidence varying with race and sex⁸. Sangeorzan *et al* demonstrated on Computed Tomography (CT) scans that the patients with severe symptomatic flat foot have significantly less contact between talus and calcaneus than controls with the foot in the weight bearing position.⁹ Subluxation of the three facets of the talocalcaneal joint does occur, in a significant number of patients with symptomatic flat foot. The subluxation is greater in the anterior/middle facets than it is in the posterior facet.⁹

Bruckner¹⁰, in contrast to the general view that configurations of articular facets of sustentaculum tali are of little functional significance, demonstrated that these are functionally important because they influence sub-talar joint stability. To test this hypothesis, Drayer-Verhagen¹¹ analysed and concluded that calcanei with two separate sustentaculum tali facets had a lower frequency of arthritic changes associated with joint instability than calcanei with other facet configuration.

Arthritic lipping was found to be significantly less common in sustentaculum tali with two separate facets than in the other configurations.

MATERIAL AND METHODS

Material for the study comprised of 200 dry (100 right and 100 left) adult calcanei of unknown age and sex. They were obtained by maceration from the cadavers available for dissection, in the department of Anatomy, Government Medical College, Amritsar.

The following points were kept in mind in the selection of the calcanei:

- 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.

All calcanei were thoroughly boiled, cleaned and numbered from 1–200 with suffix R (right) or L (left). Each bone was meticulously examined for important morphological features as described below and analysed.

Superior surface: Shape of posterior part and shape and surface area of middle part (posterior talar facet), middle talar facet and anterior talar facet was recorded. The fusion of middle and anterior articular facets, if present was recorded. The minimum distance of separation between the anterior and middle articular facets was measured by a pair of dividers on a metric scale. Talar articular facets were classified into 4 types [Type 1, 2 (A, B, C), 3, 4] based on the classification of Saadeh *et al*⁷ and Gupta *et al*¹².

Medial surface: The grooves on medial and inferior surface of sustentaculum tali were noted. The angle between anterior and middle facets was measured by Drayer-Verhagen's method.¹¹ It was measured by placing the calcaneum on its medial side on a piece of paper so that the medial border of the sustentaculum tali facets was in contact with the paper and the planes of the facets were perpendicular to the surface of the paper. The contours of the facets were traced with a pencil and the angle was measured with a protractor. An attempt was made to find out the commonest pattern of the articular facets on superior surface of calcanei in the region.

The calcanei were classified into four types.

- Type I —One continuous anterior and middle facet
- Sub type cn —The facet was constricted
- Sub type NC —The facet was not constricted
- Type II —Separate anterior and middle facet
- Sub type A —With moderate separation 5–10 mm
- Sub type B —With narrow separation <5 mm
- Sub type C —With wide separation >10 mm
- Type III —Single facet is present limited to the sustentaculum tali and no anterior facet

- Type IV —Posterior, middle and anterior facets confluent

Frequency and percentage were calculated for various types of calcanei.

RESULTS

In the present study, morphometrically 4 distinct facet patterns were identified.

Type I calcanei were 72.5% (Rt=37.5%, Lt=35%); Sub-type cn were found to be 30% (Rt=12%, Lt=18%); Sub-type NC were 42.5% (Rt=25.5%, Lt=17%).

Type II were 25.5% (Rt=11%, Lt=14.5%); Sub-type A constituted 10.5% (Rt=4.5%, Lt=6%); Sub-type B were 15% (Rt=6.5%, Lt=8.5%); Sub-type C were 0%.

Type III were found to be 1.5% (Rt=1%, Lt=0.5%); and Type IV were 0.5% (Rt=1%, Lt=0%) of the total.

Table-1: Classification of calcanei on the basis of articular facets

Types	Sub-type	Right calcanei (n=100)		Left calcanei (n=100)		Total (Rt+Lt)	
		n	%	n	%	n	%
I	cn	24	32	36	51.4	60	30.0
	NC	51	68	34	48.6	85	42.5
	Total	75	100	70	100	145	72.5
II	A	9	41	12	41.4	21	10.5
	B	13	59	17	58.6	30	15
	C	0	0	0	0	0	0
	Total	22	100	29	100	51	25.5
III	---	2	2	1	1	3	1.5
IV	---	1	1	0	0	1	0.5

The posterior part of superior surface was concavo-convex in 77.5% cases. A longitudinal ridge or an irregular eminence was occasionally found on this part. The middle part, i.e., posterior talar facet was mostly irregular convex (52.5% cases) and had a surface area of 515.78±82.64 mm² on right side and 484.46±98.41 mm² on left side. An elongated process, elevation of the superior border of a facet, i.e., arthritic lipping was also sometimes present. Anterior part had sulcus calcanei of variable depth with numerous nutrient foramina in its floor. Middle talar facet was a separate entity in 27% of the cases with most common shape being oval (19.5% cases) with an average surface area of 130.8±30.87 mm² on right side and 130.5±43.29 mm² on left side. The anterior talar facet was not fused, i.e., a separate entity in 25.5% cases with most common shape oval (20.5% cases) with an average surface area of 73.25±22.66 mm² on right side and 72±20.48 mm² on left side. In 73% cases (Incidence slightly higher than previous works) fused anterior and middle talar facets were present with most common shape being elongated (37% cases) and average surface area of 242.2±35.15 mm² on right side and 232±41.93 mm² on left side.

DISCUSSION

The results of the present study of the talar articular facets of 200 North Indian calcanei were compared with the work of the earlier workers. We could divide the various calcanei into 4 different pattern types as described by Saadeh *et al*⁷, Williams *et al*⁸, Gupta *et al*¹², Jha and Singh¹³, and Madhavi and Antonisamy¹⁴. Three different types were described by Campos and Pellico⁵, Bunning and Barnett⁶, and Drayer-Verhagen¹¹. Two facet configuration was documented by Testut¹⁵, Laidlaw¹⁶, Sharrafian¹⁷, and Padmanabhan¹⁸.

In the present study, type I calcanei was the most common (72.5%) and the observation was in consonance with previous studies where mostly the figures ranged between 60–68%. Pattern I calcaneal type was found to be dominant in the present study. Our findings confirmed the observations of other Indian studies.^{19–22} However in similar studies of an Indian population, Bunning and Barnett reported the incidence of type I calcanei somewhat higher (78%).⁶ Similar work on European population conducted by these workers showed this figure to be much lower (33%). El-Eishi has reported the incidence of type I calcanei only 49%.¹⁹

The subtype of type I calcanei constricted (cn) 30% and not constricted (NC) 42.5% cases as observed in this work can be also compared with earlier studies of Campos and Pellico⁵, Gupta *et al*¹², and Jha and Singh¹³.

The incidence of type II calcanei was 25.5% in the present study and this figure agrees with most of the previous workers who gave the incidence of type II calcanei to be 22–40%. However, much higher figures have been reported by some workers, i.e., 67% by Bunning and Barnett.⁶

Sub type A was found to be present in 10.5% cases; the study agreeing with El-Eishi, who gave the incidence as 10%.¹⁹ However these figures described by other workers are Gupta *et al*¹² (13%), Campos and Pellico⁵ (16%), and Saadeh *et al*⁷ (20.3%). Sub type B calcanei were found to be present in 15 cases comparable to El-Eishi¹⁹ who reported the incidence to be 16%. Campos and Pellico⁵ in Spanish population has given the incidence to be 24%. The incidence of sub type C described to be 14% by El-Eishi¹⁹ and 3.4% by Saadeh *et al*⁷ was not found in the present study.

In the present study the incidence of type III calcanei was 1.5% only and was lowest compared to workers reported earlier. It was highest (18.8%) in studies of Drayer-Verhagen¹¹ followed by El-Eishi¹⁹ (11%). In other studies it ranged between 2.8% and 7.6%. Bunning and Barnett⁶ and Padmanabhan¹⁸ did not observe this type of calcanei.

In the present study incidence of type IV was very low (0.5%), I was 2% in studies of both Saadeh *et*

*al*⁷ and Gupta *et al*¹². In most of the studies this type of calcanei has not been reported. However Bunning and Barnett⁶ in their studies of Veddahs (10 calcanei) reported the incidence of type IV to be 40%. This figure however is not dependable, the number of bones being very low. The middle third of superior surface of calcanei carries the posterior talar facet, oval and convex anteroposteriorly.⁸ It showed many variations in its shape and surface area.

The most common shape of the posterior talar facet was irregular and convex [IrrCx, (105, 52.5%)] with no significant difference on right and left side (Rt=27.5%, Lt=25%). It was compared to work of Williams *et al*⁸ where the most common shape has been described oval and convex (OCx). In the present study this type of shape oval and convex (OCx) was less frequent in 63 (31.5%) cases [Rt=30 (15%), Lt=33 (16.5%)]. The average surface area of posterior talar facets of right calcanei (IrrCx) was found to be 515.78±82.64 mm² and that of left calcanei (IrrCx) was 484.46±98.41 mm². The largest surface area of the post talar facet was 569 mm² on one calcaneum (0.5%) where the facet was irregular, convex and fused (IrrCxF) and where the anterior, middle and posterior facets were fused together (Type IV calcanei). The smallest surface area noted was 260 mm² on one calcaneum (0.5%), where the facet was elliptical irregular convex (EpIrrCx). These parameters could not be compared due to lack of availability of the literature.

One bone had an elongated process 15×7 mm directed superiorly. One bone had a very prominent posterior facet on upper margin along with 3×7 mm depression on lateral border of posterior facet. In one bone the superior border of posterior talar facet was elevated (Arthritic lipping¹¹). One bone had a depressed middle part. Anterior part of the calcaneum presents sulcus calcanei, middle talar facet and anterior talar facet. Sulcus calcanei begins from a narrow depression closer to posterior talar facet and narrows into a groove on the medial side. It showed variation in its depth. In the anterior part of superior surface the middle (present on superior surface of sustentaculum tali) and anterior talar facets were found to be either fused with each other or exist as separate entities. These findings were compared with those of the previous workers. The incidence of fused facet (72.5%) was found to be somewhat higher than that of previous workers in the present study.

Table-2: Comparison of the present study with earlier work

Workers	Year	No. of calcanei	Fused (%)	Non-Fused (%)
Drayer-Verhagen	1993	191	54.5	26.7
Williams <i>et al</i>	2000	401	67	26
Saadeh <i>et al</i>	2000	300	63	30.3
Present study	2014	200	72.5	25.5

Table-3: Comparison of incidence of fused/non-fused anterior and middle talar facets

Middle and anterior talar facets	Total (200)		Rt (100)		Lt (100)	
	n	%	n	%	n	%
Fused	145	72.5	75	37.5	70	35
Non-fused	51	25.5	22	11	29	14.5
Only middle talar facet present	3	1.5	2	1	1	0.5
Anterior, middle and posterior talar facets fused	1	0.5	1	0.5	0	0

The middle talar facet was present as a separate facet on superior surface of sustentaculum tali in 54 cases (27%), out of these in three cases the anterior talar facet was absent. The shape and surface area of this facet showed following variations.

This middle talar facet was present as a separate (non-fused) facet in 24 (12%) cases on right side and 30 (15%) cases on left side. The most common shape of facet was oval (O) in 39 (19.5%) cases [Rt=17 (8.5%), Lt=22 (11%)]. The least common shape was oval irregular (Oirr) in one (0.5%) case.

The surface area of facet showed wide variation; was large in oval (O) shaped ($130.65 \pm 37.08 \text{ mm}^2$) mostly. A small percentage (1.5%) fell in lower surface area range ($91.5 \pm 0.707 \text{ mm}^2$) in round (R) shaped facet. Comparative figures could not be found in the available literature. The anterior talar facet was found as a separate entity (non-fused) in 51 (25.5%) [Rt=22 (11%), Lt=29 (14.5%)]. The shape and surface area showed a wide variation as tabulated below.

Table-4: Shape and surface area of middle talar facet

Shape	n	%	Right			Left		
			n=24	%	Surface area (mm ²)	n=30	%	Surface area (mm ²)
Elongated (El)	8	4	4	2	110.5±32.89	4	2	133.8±35.62
Irregular (Irr)	3	1.5	---	---	---	3	1.5	123.8±47.14
Oval (O)	39	19.5	17	8.5	130.8±30.87	22	11	130.5±43.29
Oval Irregular (Oirr)	1	0.5	1	0.5	114	---	---	---
Round (R)	3	1.5	2	1	91.5±0.707	1	0.5	58
Total	54	27	24	12	---	30	15	---

Table-5: Shape and surface area of anterior talar facet

Shape	Total (n)	Total (%)	Right			Left		
			n=24	%	Surface area (mm ²)	n=30	%	Surface area (mm ²)
Elongated (El)	4	2	---	---	---	4	2	53.25±12.82
Irregular (Irr)	2	1	---	---	---	2	1	49±2.828
Oval (O)	41	20.5	20	10	73.25±22.66	21	11.5	72±20.58
Pear	1	0.5	---	---	---	1	0.5	46
Round (R)	2	1	1	0.5	62	1	0.5	34
Triangular (T)	1	0.5	1	0.5	30	---	---	---
Total	51	25.5	22	11	---	29	14.5	---

The most common shape of anterior talar facet was oval (O) in 41 (20.5%) [Rt=20 (10%), Lt=21 (10.5%)]. The least common shape was pear and triangular shape being 0.5% each. The anterior talar facet was absent in 3 (1.5%) cases, 2 cases on right and 1 case on left side (type III calcanei).

The surface area of facets showed wide variations was large in oval (O) shaped facet ($72.625 \pm 20.62 \text{ mm}^2$) and was smallest (30 mm^2) in triangular (T) facet. Comparative studies are not available.

The middle and anterior talar facets were fused in 146 (73%) cases, [Rt=76 (38%), Lt=70 (35%)]. The shape and surface area showed a wide range of variations. The most common shape of fused facets was elongated (El) 74 (37%) cases [Rt=37 (18.5%), Lt=37 (18.5%)]. The irregular (Irr) shape was found in 21 (10.5%) cases [Rt=12 (6%), Lt=9 (4.5%)]. The facet was oval (O) in 15 (7.5%) cases [Rt=10 (5%), Lt=5 (2.5%)]. Elongated constricted (Elcn) was present in 14 (7%) cases [Rt=4 (2%), Lt=10 (5%)]. The rest all shapes were much less in frequency.

The surface area mostly fell in the range of $242.2 \pm 35.15 \text{ mm}^2$ (Elongated facet). In one case where the facet was curved hockey stick shaped the surface area was very large (326 mm^2). The lowest surface area noted was in irregular elongated (IrrEl) facet (201 mm^2). In one case the anterior, middle and posterior talar facet were fused with each other (IrrF, type IV calcaneum) and the surface area was 569 mm^2 .

The articular facets of the sustentaculum tali have a variety of configurations that were earlier generally viewed as non-metric traits of little functional significance. Bruckner¹⁰, in contrast, had hypothesised these facet variations to the general view that configurations of articular facets are functionally important because they influence sub-talar joint stability. Joints with two-facet configuration are comparatively more stable.

Drayer-Verhagen¹¹ reached the conclusion that calcanei with two separate sustentaculum tali facets had a lower frequency of arthritic changes associated with joint instability than calcanei with other facet configuration. Arthritic lipping was found to be significantly less common in sustentaculum tali with

two separate facets than in the other configurations, thus 25.5% of the population examined had more stable joints and less arthritic changes.

The medial surface was vertically concave; its concavity was accentuated by the sustentaculum tali. Sustentaculum tali was a shelf like process from the medial surface bearing middle anterior talar facet on its superior surface, having groove for the tendon of flexor hallucis longus (FHL) on its medial surface and groove for flexor digitorum longus (FDL) on its medial aspect.

The angle formed by the intersection of the anterior and middle facets of the sustentaculum tali was measured and compared. The average intersecting angle of type I calcanei, which was 150.52° in the present study tallied with 149.1° that of Drayer-Verhagen¹¹ though the standard deviation was higher in the present study. In Type II and Type III calcanei the intersecting angle was higher than that of Drayer-Verhagen. In Type IV calcanei the intersecting angle was 160° and this type was not observed by Drayer-Verhagen.¹¹

Table-6: Comparison of intersecting angles (degrees)

Type	Drayer-Verhagen (1993)		Present study (2014)	
	Mean±SD	Range	Mean±SD	Range
Type I	149.1±8.59	128.5–161.5	150.52±10.39	123–180
Type II	127.8±10.06	107–146	136.9±12.36	116–178
Type III	136.05±11.15	113–157.5	155.3±9.5	146–165
Type IV	---	---	160	---

CONCLUSION

The articular facets of subtalar joint on calcanei show racial and individual differences. Study population may be at greater risk of developing subtalar arthritis due to predominant pattern I calcanei compared to the Europeans who present pattern II commonly. There is need to modify western surgical techniques to suit the Indian scenario especially for orthopaedic surgeons in India for calcaneal osteotomy.

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