# AN ANATOMICAL STUDY OF MORPHOLOGY AND MORPHOMETRIC ANALYSIS OF CALCANEUM AND ITS TALAR ARTICULAR SURFACES

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### ABSTRACT

**Background and Aims:** Calcaneum, also called as the "Heel Bone" is the largest and strongest tarsal bone in humans. It acts as the posterior pillar of the longitudinal arches of foot for the transmission of body weight. The Calcaneum articulates with the Talus bone superiorly by three articular facets, forming a Subtalar joint. In the present study, the variations of the Talar articular facets on the Calcaneum, presence of Calcaneal spur are observed along with morphometric analysis of Calcaneum.

Materials and Methods: 110 dry Calcaneal specimens from the Department of Anatomy of our institution are used for this study. Digital vernier caliper is used for morphometric analysis.

**Observations:** The Calcaneum is classified into different types based on the Talar articular facets. The presence of dorsal and plantar or inferior Calcaneal spur is observed and it is correlated with the different types of Calcaneum. Other morphometric parameters are also observed. The gender of the bone is not considered in the present study.

**Conclusion:** Subtalar joint stability is influenced by the morphology of Talar articular facets on the Calcaneum. Facet morphology can be determined by the gait pattern or other environmental and genetic factors. A proper knowledge of the anatomy of Calcaneum and their variations in different parameters is necessary for a good clinical understanding and treatment outcome.

**KEY WORDS**: Calcaneum, Talar articular facets, Calcaneal spur.

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### **INTRODUCTION**

The Calcaneum, also known as the "Heel Bone" is the largest of the seven tarsal bone of the foot. It is the first bone of the foot to ossify. It is the strongest tarsal bone which acts as the posterior pillar for the longitudinal arches of foot and also aids in transmission of body weight. The Calcaneum articulates with the Talus superiorly to form Subtalar joint.

The superior or the dorsal surface of the Calcaneum usually bears three articular facets for its articulation with the Talus. Based on the Anbumani T L, Sridharan R, Thamarai Selvi A. AN ANATOMICAL STUDY OF MORPHOLOGY AND MORPHOMETRIC ANALYSIS OF CALCANEUM AND ITS TALAR ARTICULAR SURFACES.

placement of the articular surface, they are named as anterior, middle and posterior articular facets. The middle articular facet is situated over the Sustentaculam tali of the Calcaneum. Calcaneum is classified into different types based on the Talar articulation facets.

Studies showing variations of the Talar articular facets are available in literatures. Bunning and Barnett in 1963 have observed three different types of variations of Talar articular facets on the Calcaneum [1]. The posterior Calcaneal facet for Talus does not show much of variations, however, the variations of the anterior and middle Calcaneal facet for Talus are correlated with race [2].

The development of Calcaneal spur has been hypothesized to be the skeletal response to stress. Calcaneal spur are of two types, namely the dorsal spur and the inferior or plantar spur. In the Present study, the presence of Calcaneal spur is correlated with the type of Calcaneum.

Variations in the Calcaneal facet for Talus can influence the subtalar stability [3]. Hence a proper knowledge of the anatomy of Calcaneum and their variations in different parameters is necessary for a good clinical understanding and treatment outcome.

### **MATERIALS AND METHODS**

110 human, adult, dry Calcaneji from the Department of Anatomy of our institution are used for this study. The pattern of the Talar articular facets on the Calcaneum was observed.

The total length of the Calcaneum in horizontal position was measured, taking anterior most part of Cuboidal articular facet on the Calcaneum as anterior end and attachment for tendocalcaneus as posterior end. Interfacet distances, namely the distance between anterior and middle facet and between anterior and posterior Talar articular facets are measured. Digital vernier caliper is used for taking measurements.

# **OBSERVATION AND RESULTS**

Of the total 110 Calcaneii which are used for this study, 65 are right sided and 45 are left sided. The Calcaneii are classified into three major types as Type A, Type B and Type C, based on the number of articular facets for the Talus on its superior aspect. **Fig. 1:** Left Calcaneum showing three separate articular facets for Talus. (Type A)



AF- Anterior facet ; MF- Middle facet ; PF- Posterior facet **Fig. 2:** Right Calcaneum showing fused anterior, middle and posterior talar articular facets. (Type C)



AF- Anterior facet ; MF- Middle facet ; PF- Posterior facet **Fig. 3:** Right Calcaneum showing fused anterior and middle talar facets without a notch in between them. Posterior facet is separate. (Type B1)



AF- Anterior facet ; MF- Middle facet ; PF- Posterior facet

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**Fig. 4:** Right Calcaneum showing fused anterior and middle talar facets with a notch in between them. Posterior facet is separate. (Type B2)



AF- Anterior facet ; MF- Middle facet ; PF- Posterior facet Fig. 5: Right Calcaneum showing middle and posterior talar facets. Anterior facet is absent. (Type B3)



MF- Middle facet ; PF- Posterior facet

Fig. 6: Right Calcaneum showing fused middle and posterior talar facets. Anterior facet is separate. (Type B4)



AF- Anterior facet ; MF- Middle facet ; PF- Posterior facet

**Fig. 7:** Right Calcaneum showing both dorsal and plantar Calcaneal spur.



DS- Dorsal Calcaneal Spur; PS- Plantar Calcaneal Spur **Type A:** Presence of three separate articular facets, namely anterior, middle and posterior facets **(Figure 1)** 

**Type B:** Presence of two articular facets for Talus on the Calcaneum

**Type C:** Presence of single fused articular facet for Talus on the Calcaneum (Figure 2)

Table 1 shows the percentage incidence of types of Calcaneum.

Table 1: Percentage of incidence of types of Calcaneum.

| Type Of   | Right Side Calcaneum |            | Left Side       | Calcaneum  | Total           |            |  |
|-----------|----------------------|------------|-----------------|------------|-----------------|------------|--|
| Calcaneum | No. of<br>Bones      | Percentage | No. of<br>Bones | Percentage | No. of<br>Bones | Percentage |  |
| Туре А    | 16                   | 14.5       | 8               | 7.3        | 24              | 21.8       |  |
| Туре В    | 46                   | 41.8       | 36              | 32.7       | 82              | 74.5       |  |
| Туре С    | 3                    | 2.7        | 1               | 0.9        | 4               | 3.6        |  |
| Total     | 65                   | 59         | 45              | 41         | 110             | 100        |  |
| */ 110)   |                      |            |                 |            |                 |            |  |

#### \*(n=110)

Table 2: Percentage incidence of subtypes of Type BCalcaneum.

| Subtypes Of Type B | Right Side Calcaneum |            | Left Side Calcaneum |            | Total           |            |
|--------------------|----------------------|------------|---------------------|------------|-----------------|------------|
| Calcaneum          | No. Of<br>Bones      | Percentage | No. Of<br>Bones     | Percentage | No. Of<br>Bones | Percentage |
| Type B1            | 24                   | 21.8       | 17                  | 15.4       | 41              | 37.2       |
| Type B2            | 20                   | 18.1       | 15                  | 13.6       | 35              | 31.8       |
| Type B3            | 1                    | 0.9        | 3                   | 2.7        | 4               | 3.6        |
| Type B4            | 1                    | 0.9        | 1                   | 0.9        | 2               | 1.8        |
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Type B is further classified into four subtypes as follows:

**Type B1:** Anterior and middle facets are completely fused. (Figure 3)

Type B2: Anterior and middle facets are fused with the presence of a notch in between them. (Figure 4)

**Type B3:** Anterior facet is absent. Only middle and posterior facets are present. (Figure 5)

**Type B4:** Middle and posterior facets are fused with each other. Anterior facet is separate. **(Figure 6)** 

Type B1 and B2 Calcaneii, in which the anterior and middle Talar facet are fused, is found in 76 bones which correspond to 69.1% of the bones.

The Interfacet distance between anterior and middle facets are measured in Type A and Type B4 Calcaneum. Table 3 shows the percentage incidence of Calcaneum as per interfacet distance between anterior and middle Talar facets.

 Table 3: Percentage incidence of Calcaneum based on anterior and middle interfacet distance.

| Distance Between | Right Side Calcaneum |            | Left Side       | Calcaneum  | Total           |            |
|------------------|----------------------|------------|-----------------|------------|-----------------|------------|
| Facet            | No. Of<br>Bones      | Percentage | No. Of<br>Bones | Percentage | No. Of<br>Bones | Percentage |
| < 2 mm           | 8                    | 7.3        | 5               | 4.5        | 13              | 11.8       |
| 2-5 mm           | 7                    | 6.4        | 3               | 2.7        | 10              | 9.1        |
| 5-10 mm          | 2                    | 1.8        | 1               | 0.9        | 3               | 2.7        |
| Total            | 17                   | 15.5       | 9               | 8.1        | 26              | 23.6       |

The Interfacet distance between the anterior and posterior facets are measured in 106 bones out of 110 Calcaneum, as the anterior facet is absent in four bones. The interfacet distance ranged between 7mm to 20mm with a mean of 15mm.

The horizontal length of the Calcaneum was measured between the Cuboid articular facet anteriorly and the attachment for tendocalcaneus posteriorly. The length ranged between 5.5cm to 8.5cm, with a mean of 7.5cm. Table 4 shows the length of the right and left side Calcaneii.

| Side Of The Calcaneum | 5.5 - 6.5 cm | 6.6 - 7.5 cm | 7.6 - 8.5 cm | Total |
|-----------------------|--------------|--------------|--------------|-------|
| Right Calcaneum       | 8            | 32           | 25           | 65    |
| Left Calcaneum        | 5            | 22           | 18           | 45    |
| Total                 | 13           | 54           | 43           | 110   |

Table 4: Horizontal Length of the Calcaneum.

Correlation between the increase in length of the Calcaneum to the increase in interfacet distance is looked for in this study. There was no significant correlation between the length of the Calcaneum and the interfacet distances.

The presence of Calcaneal spur is observed in 47% of the bones in this study. Two types of Calcaneal spurs are noted, namely the Dorsal Calcaneal spur and Plantar or inferior Calcaneal spur with an incidence of 8% and 27%

respectively. 12% of Calcaneum had both dorsal and inferior spurs (Figure 7). Table 5 and Table 6 shows the correlation of Calcaneal spurs to the type of Calcaneum and their percentage incidence respectively.

Table 5: Calcaneal spur and its correlation to the type ofCalcaneum.

| Type Of   | Type Of Right Side Calcaneum |                  |      |       | Left Side Calcaneum |                  |      |       |
|-----------|------------------------------|------------------|------|-------|---------------------|------------------|------|-------|
| Calcaneum | Dorsal<br>Spur               | Inferior<br>Spur | Both | Total | Dorsal<br>Spur      | Inferior<br>Spur | Both | Total |
| Туре А    | 1                            | 3                | 1    | 5     | 0                   | 3                | 1    | 4     |
| Туре В    | 4                            | 14               | 5    | 23    | 3                   | 9                | 6    | 18    |
| Туре С    | 0                            | 1                | 0    | 1     | 1                   | 0                | 0    | 1     |
| Total     | 5                            | 18               | 6    | 29    | 4                   | 12               | 7    | 23    |

Table 6: Percentage incidence of Calcaneal spurs to thetype of Calcaneum.

| Type Of   | No. Of Calca<br>Sp | aneum With<br>ur  | Total | Percentage |  |
|-----------|--------------------|-------------------|-------|------------|--|
| Calcaneum | Right<br>Calcaneum | Left<br>Calcaneum | Total |            |  |
| Type A    | 5                  | 4                 | 9     | 8          |  |
| Туре В    | 23                 | 18                | 41    | 37         |  |
| Туре С    | 1                  | 1                 | 2     | 2          |  |
| Total     | 29                 | 23                | 52    | 47         |  |

In the present study, 41 out of 52 Calcaneal spurs are present in type B Calcaneum. Inferior Calcaneal spur is present in 30 bones. Dorsal Calcaneal spur is observed in 9 Calcaneum. Inferior Calcaneal spur is more common than the dorsal Calcaneal spur. Both dorsal and inferior spur are observed in 13 Calcaneum.

# DISCUSSION

The Calcaneum articulates with the Talus superiorly to form the Subtalar joint. Talar facet morphology of the Calcaneum is an important factor for the integrity of the Subtalar joint [4]. The "Osseous Tripod" pattern in which there are three articular facets for Talus on Calcaneum, gives a better stability for the Subtalar joint. The purpose of this study is to analyse the incidences of variations of types of Calcaneum in its morphology and morphometric patterns in the state of Tamil Nadu, India.

Bunning and Barnett [1] in 1963 have reported three variations in the types of Calcaneum. They are as follows:

Type-A: There are three facets separated by variable intervals.

Type-B: There are two facets anterior and middle

which are either continuous or have a notch between them.

Type-C: There is only one facet i.e. the three forms a continuum.

All the three types of Calcaneii are found in the present study in the frequencies of 21.8% of Type A, 74.5% of Type B and 3.6% of Type C Calcaneii. Type B1 & B2 Calcaneum (69.1%), with fused anterior and middle facet and a separate posterior facet is the commonest type of Calcaneum observed in this study.

This is different from that of Bunning and Barnett [5] study among British population, where the Type A Calcaneum with three separate articular facets was more common. i.e., 67%.

A study by Barbaix et al [6] in Belgian population has also reported that Type A Calcaneum is more common, which is 64% when compared to Type B Calcaneum.

Chart 1: Comparison Of Type A And Type B (B1 & B2) Calcaneii In The Present Study With Other Studies.



In a study by Muthukumaravel et al [7] on 237 Calcaneum in Tamil Nadu, 33.33% of bones had three separate articular facets and 65.82% had two articular facets, with fused anterior and middle facets for Talus, that corresponds to Type A (22%) and Type B1 & B2 (69%) of present study respectively.

Both the studies have similarity in the increased incidence of two Talar articular facets when compared to three Talar articular facets on the Calcaneum, however the percentage of Type B Calcaneum is more in the present study than that of the study by Muthukumaravel et al [7].

However the present study correlates well with the study by Bunning and Barnett [5] in Indian population on 78 Calcaneii, but the results is quite different on the Britain population, where the three facet morphology is more common than the two facets Calcaneii. The racial differences of the Calcaneum have also been studied by them on the foetal Calcaneum with similar results, thereby depicting a genetic cause behind the varying facet pattern on different population. The study by El-Eishi [8] in 200 Egyptian Calcaneii has also reported increased incidence of Type B Calcaneii (49%) than Type A (40%). However the incidence of Type B (B1 & B2) Calcaneii in the present study is 69%, which is much higher.

The anterior articular facet for Talus is absent in 3.6% of bones (TYPE B3) in the present study, which is lower than that of Priya et al [9] study with 7.04% incidence. In the present study, fusion of middle and posterior facet with separate anterior facet is reported in 1.8% of bones (TYPE B4), which is rarely reported in literatures.

A single fused articular facet for Talus in the Calcaneum is reported in 3.6% of bones in the present study, which is much higher than the study by Muthukumaravel et al (0.42%) [7]. This type of Calcaneum is not reported in Priya et al [9] study. In the present study, the anterior and middle Talar facets in Type B Calcaneii are fused in two different formats. In Type B1, they are fused completely (37%). In Type B2, there is a notch between the two facets (32%). The results are similar to that of a study by Jha and Singh [10], however the incidence of Type B2 is much higher in the present study than by Jha and Singh [10] study (11.87%).

In the present study, the anterior and middle interfacet distance is less than 2mm in 11.8% of bones and in 9.1% of Calcaneum, the distance ranged between 2mm to 5mm. The results are similar to the results of the study by Bhanu Sudha Parimala N et al [11].

Therefore, in the present study, the interfacet distance between anterior and middle facet is less than 5mm in majority of the Calcaneum.

Bruckner's [3] hypothesis and the findings of Francine D V [4] have stated that Talar facet morphology is the key for subtalar joint stability. The three facet morphology of the Calcaneum has better stability and is less prone for arthritis. The Osseous Tripod appearance of Talus on Calcaneum offers less mobility for the Talus over the Calcaneum, thereby preventing injuries and strain to the Talus over the Calcaneum. However studies indicate that the Indian populations have more number of two facet morphology of the Calcaneum leading on to increased incidence of Osteoarthritis.

In the present study, two types of Calcaneal spur has been observed. The Dorsal spur and the Plantar or the Inferior spur and it has been correlated with the Type of Calcaneum. 47% of the Calcaneum has spur, of which 37% are found in Type B Calcaneii, which is similar to Jagdev Singh et al study [12]. The incidence of Calcaneal spur is much higher in the present study, than that of Jagdev Singh et al [12] study (26.5%).

In the present study, Plantar spur (27%) is more common than the Dorsal spur (8%), which is similar to the study of Bassiouni [13]. However Jagdev Singh et al [12] study have reported higher incidence of dorsal Calcaneal spur (15.5%) than the inferior Calcaneal spur (6.5%).

Chart 2 shows the incidence of various types of Calcaneal spur in various studies.

Chart 2: Comparison of Incidence of various types of Calcaneal Spur In Various Studies.



Various factors have been related to the development of Calcaneal spur like increase in age, obesity, ethnicity, physical activity etc. Li and Muehleman[14] have stated that the bony trabeculae in the spur were aligned in the direction of stress and not along the soft tissue traction, thereby emphasizing the hypothesis that Calcaneal spur is a skeletal response to stress during walking, running etc.

Bassiouni [13] has reported that 81% of patients with osteoarthritis had Calcaneal spur when compared to the controls. Various studies have reported that patients with two facet configuration with fused anterior middle facet and separate posterior facet have lesser stability and are more prone for osteoarthritis. Also the literatures have cited that this type of configuration is dominant in Indians. Thereby Indians are more prone for osteoarthritis and also for the development of Calcaneal spur resulting in Heel pain.

Thereby in the present study on the Calcaneum of Tamil Nadu, India, the incidence of Type B Calcaneum with fused anterior middle Talar facet and a separate posterior facet is higher and also the Calcaneal spur formation are more common in Type B Calcaneum, thereby correlating the relation of Subtalar Osteoarthritis and Calcaneal Spur formation to the Talar facet morphology on the Calcaneum.

# CONCLUSION

A thorough knowledge of pattern of Talar facets on the Calcaneum and their variations is essential for providing the best treatment in various clinical conditions. An insight into the racial differences in facet pattern is vital in carrying out surgical procedures like Calcaneal Osteotomy. Hence this study is accomplished to contribute to the subject of Anatomy enlightening the importance of variations in the normal Anatomy.

# **Conflicts of Interests: None**

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