

## A morphological and morphometric study of human calcanei and their articular facets

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### Abstract

**Introduction:** Calcaneum is the longest, strongest and biggest of all the tarsal bones of the proximal row. Anterior and posterior articulations between the calcaneus and talus form a functional unit termed the talocalcaneal or subtalar joint. Talocalcaneal joint maintains eversion and inversion of the foot. Differences with respect to race, as well as individual characteristics, suggest that the articular facets play a key role in both static and dynamic kinetics of the foot and ankle.

**Materials and Methods:** The present study was carried out with 50 calcanei, 25 bones of right side and 25 bones of left side of unknown sex which were obtained from the Department of Anatomy, Government Medical College, Amritsar. Any calcaneum looking pathological on general examination was discarded from the study. All the parameters were taken by using standard digital vernier calliper which is capable of measuring to the nearest of 0.01mm.

**Aim:** The study seeks to observe the variations in the morphology and morphometry of the talar articular facets on the superior surface of dry calcaneal bones of adult human

**Results:** Type I - Fused anterior and middle talar facet with a separate posterior facet in 33 cases - 66% (Rt 18 cases - 36%, Lt 15 cases - 30%), Type II - Separate anterior and middle talar facet in 10 cases - 20% (Rt 5 cases - 10%, Lt 5 cases - 10%), with a separate posterior talar facet, Type III - Absence of anterior articular facet in 2 cases - 4% (Rt 1 case - 2%, Lt 1 case - 2%) and Type IV - All the three facets i.e. anterior, middle and posterior facets were seen on the superior surface of the calcaneus but anterior and middle facets incompletely separated from each other in 5 cases - 10% (Rt 1 cases - 2%, Lt 4 cases - 8%).

**Conclusion:** The individual and racial differences of the anatomic construction of calcaneal talar articular facets influence the static and kinetic dynamics of foot.

**Keywords:** Calcaneum, Talar articular facets, Subtalar joint.

### Introduction

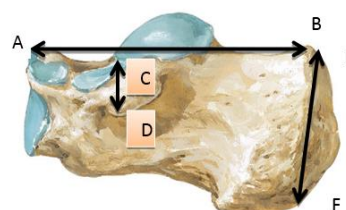
Calcaneum is the longest, strongest and biggest of all the tarsal bones of the proximal row.<sup>1,2</sup> It is also referred to as heel bone and forms a major component of the skeleton of the hindfoot and prominence of the heel. This bone is unique, since it is the first tarsal bone to ossify. The purpose of the calcaneus is to transmit the weight of the body to the ground and act as a strong lever for the calf muscles.<sup>3,4</sup> It is well designed to sustain high tensile, bending and compressive forces. However, high instantaneous loads often result in fracture.<sup>5</sup> It is located posteroinferior to the talus, providing support to the ankle joint. It measures about 3.5 inches in length and about 1.5 inch at its widest point.<sup>6,7</sup> Calcaneum fractures are also known as "Lover's Fracture," or "Don Juan Fracture." The name lover's fracture is derived from the fact that a lover may jump from great heights while trying to escape from the lover's spouse.<sup>8</sup> If untreated, they can interfere with normal coupled motion of ankle and subtalar joint and result in permanent pain, loss of motion and deformity.<sup>9</sup> The morphology of human calcanei and their articular facets is of interest to anatomists, but more importantly the relationship is critical in anthropometry, kinesiology, orthopaedic surgery, physical therapy and rehabilitation. Differences with respect to race, as well as individual characteristics, suggest that the articular

facets play a key role in both static and dynamic kinetics of the foot and ankle.<sup>10-12</sup> The present study was designed to attain a complete knowledge about morphology and morphometry of talar articular facets.

### Materials and Methods

Material for the present study comprised of 50 (25 right and 25 left) calcanei which were obtained from the Department of Anatomy, Government Medical College, Amritsar.

Any calcaneum looking pathological on general examination was discarded from the study. These were labelled from 1-50 with suffix R(Right) or L(Left). Study will be conducted after taking approval of Institutional Ethics Committee, Government Medical College, Amritsar.



**AB:** Length; **CD:** Breadth; **EF:** Height  
**Fig. 1: Measurements of calcaneum**

Each calcaneum was carefully examined for various types of articulating facets for talus and were categorised into four types.

**Type I** - Fused anterior and middle talar facet with a separate posterior facet

Sub type cn: The fused facet was constricted

Sub type NC: The fused facet was not constricted

**Type II:** Separate anterior and middle talar facet

Sub type A: With narrow separation <2mm

Sub type B: With moderate separation 2- 5 mm

Sub type C: With wide separation >5mm

**Type III:** Absence of anterior articular facet

**Type IV:** All the three facets i.e. anterior, middle and posterior facets were seen on the superior surface of the calcaneus but anterior and middle facets incompletely separated from each other.

### Results

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, height and breadth of right and left calcaneus at level of significance.

**Table 1: Gross anatomical dimensions of calcanei (50)**

| Dimensions        | Right<br>n = 25 | Left<br>n = 25 | Total<br>n=50 | t-value | p-value |
|-------------------|-----------------|----------------|---------------|---------|---------|
|                   | Mean±S.D.       | Mean±S.D.      | Mean±S.D.     |         |         |
| <b>1. Length</b>  | 67.6±6.05       | 70.28±5.39     | 68.94±1.89    | 1.98    | 0.05    |
| <b>2. Breadth</b> | 36.84±3.48      | 40.56± 6.1     | 38.70±2.63    | 2.64    | 0.01    |
| <b>3. Height</b>  | 42.40±8.32      | 45.08±7.04     | 43.24±4.00    | 1.22    | 0.22    |

It was found that there were no statistically significant differences in the average values of right and left calcanei in their gross anatomical dimensions i.e length, breadth and height.

**Table 2: Shape and surface area of fused anterior and middle talar facets**

| Shape                        | Right |    |                                 | Left |    |                                 | Total |    |
|------------------------------|-------|----|---------------------------------|------|----|---------------------------------|-------|----|
|                              | N     | %  | Surface area (mm <sup>2</sup> ) | N    | %  | Surface area (mm <sup>2</sup> ) | N     | %  |
| Elongated (El)               | 12    | 24 | 260.84±124.92                   | 12   | 24 | 194.45±39.23                    | 24    | 48 |
| Elongated constricted (Elcn) | 8     | 16 | 233.82±82.53                    | 8    | 16 | 233.5±68.04                     | 16    | 32 |
| Total                        | 20    | 40 | ---                             | 20   | 40 | ---                             | 40    | 80 |

In the present study, the most common shape of fused anterior and middle facets was elongated (El) in total 24 cases – 48% (Rt 12 cases – 24%, Lt 12 cases – 24%). Elongated constricted (Elcn) was present in 16 cases – 32% (Rt 8 cases – 16%, Lt 8 cases – 16%). The surface area of right side fell in the range of 260.84±124.92 mm<sup>2</sup> (Elongated) and on left side was 194.45±39.23mm<sup>2</sup> (Elongated).

**Table 3: Shape and surface area of middle talar facet**

| Shape     | Right |    |                                 | Left |    |                                 | Total |    |
|-----------|-------|----|---------------------------------|------|----|---------------------------------|-------|----|
|           | N     | %  | Surface Area (mm <sup>2</sup> ) | N    | %  | Surface area (mm <sup>2</sup> ) | N     | %  |
| Oval (O)  | 4     | 20 | 101.25±34.08                    | 5    | 10 | 114±11.53                       | 9     | 18 |
| Round (R) | 1     | 2  | 50.00                           | 0    | 0  | ---                             | 1     | 2  |
| Total     | 5     | 10 | ---                             | 5    | 10 | ---                             | 10    | 20 |

In the present study, the most common shape of middle talar facet was oval (O) in 9 cases – 18% (Rt 4 cases – 20%, Lt 5 cases – 10%). The least common shape was round (R) in one case (2%). The surface area of facet was large in oval (O) shaped (Rt 101.25±34.08 mm<sup>2</sup>, Lt 114±11.53mm<sup>2</sup>) and small in round (R) shaped (Rt 50.00mm<sup>2</sup>).

**Table 4: Shape and surface area of anterior talar facet**

| Shape                 | Right |    |                                 | Left |    |                                 | Total |    |
|-----------------------|-------|----|---------------------------------|------|----|---------------------------------|-------|----|
|                       | N     | %  | Surface Area (mm <sup>2</sup> ) | N    | %  | Surface Area (mm <sup>2</sup> ) | N     | %  |
| Irregular (Irr)       | 0     | 0  | ---                             | 1    | 2  | 0                               | 1     | 2  |
| Oval (O)              | 1     | 2  | 30                              | 0    | 0  | ---                             | 1     | 2  |
| Oval Irregular (OIrr) | 1     | 2  | 86                              | 1    | 2  | 34                              | 2     | 4  |
| Round (R)             | 3     | 6  | 44±120.65                       | 3    | 6  | 64.5±3.54                       | 6     | 12 |
| Total                 | 5     | 10 | ---                             | 5    | 10 | ---                             | 10    | 20 |

In the present study, the most common shape of anterior talar facet was found to be round (R) in 6 cases – 12% (Rt 3 cases – 6%, Lt 3 cases – 6%) while the least common shape was irregular (Irr) with a incidence of 2%.



**Fig. 2: Showing type I(CN) fused anterior and middle talar facets with a constriction in between**



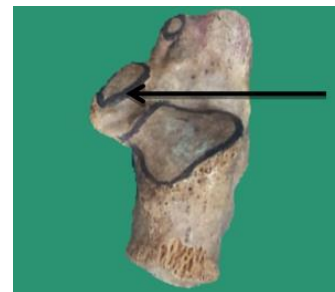
**Fig. 3: Showing type I (NC) fused anterior and middle talar facets**



**Fig. 4: Showing type II subtype A with narrow separation <2mm**



**Fig. 5: Showing type II subtype B with moderate separation 2-5 mm**



**Fig. 6: Showing type II subtype C with wide separation >5 mm**



**Fig.7: Showing type III absence of anterior articular facet**



**Fig. 8: Showing type IV- all the three facets i.e. anterior, middle and posterior talar facets were seen on the superior surface of the calcaneus but anterior and middle talar facets incompletely separated from each other**

## Discussion

The racial and sexual variations in the morphology of talar articular facets of calcaneum is well documented by earlier researchers. Four different pattern types as described by Jha and Singh,<sup>13</sup> Gupta et al,<sup>14</sup> Saadeh et al<sup>15</sup> and Kullar J S et al.<sup>16</sup> Three different types were described by Campos and Pellico,<sup>17</sup> Bunning and Barnett<sup>12</sup> and Drayer-Verhagen.<sup>18</sup> Two facet configuration was documented by Testut,<sup>19</sup> Laidlaw,<sup>20</sup> Sharrafian S K<sup>21</sup> and Padmanabhan.<sup>22</sup> However, we chose the four different pattern grouping as it best categorizes the patterns of the talar facets observed in the present study.

**Table 5: Comparison of types of articular facets of calcanei**

| No | Workers                            | Year | N    | (% of types of calcanei) |       |       |       |      |      |     |       |      |      |
|----|------------------------------------|------|------|--------------------------|-------|-------|-------|------|------|-----|-------|------|------|
|    |                                    |      |      | I                        | Cn    | NC    | II    | A    | B    | C   | III   | IV   | V    |
| 1  | Bunning and Barnett <sup>12</sup>  | 1965 | 194  | 33                       | --    | --    | 67    | --   | --   | --  | --    | --   | --   |
| 2  | Jha and Singh <sup>13</sup>        | 1972 | 1600 | 59.5                     | 33.75 | 25.75 | 37.5  | --   | --   | --  | 2.87  | 0.12 | --   |
| 3  | Gupta et al <sup>14</sup>          | 1977 | 401  | 67                       | --    | --    | 26    | --   | --   | --  | 5     | 2    | --   |
| 4  | Drayer-Verhagen <sup>18</sup>      | 1993 | 191  | 54.45                    | --    | --    | 26.7  | --   | --   | --  | 18.85 | --   | --   |
| 5  | Campos and Pellico <sup>17</sup>   | 1989 | 176  | 54                       | 29    | 25    | 40    | 16   | 24   | --  | 6     | --   | --   |
| 6  | Saddeh et al <sup>21</sup>         | 2000 | 300  | 63                       | --    | --    | 30.3  | 20.3 | 6.7  | 3.4 | 4.7   | 2    | --   |
| 7  | Muthukumaravel et al <sup>23</sup> | 2011 | 237  | 65.82                    | --    | --    | 33.33 | --   | --   | --  | --    | 0.42 | 0.42 |
| 8  | Garg R et al <sup>24</sup>         | 2013 | 310  | 72.26                    | --    | --    | 24.52 | --   | --   | --  | 1.3   | 1.6  | 0.32 |
| 9  | Chavan et al <sup>25</sup>         | 2014 | 60   | 68.33                    | --    | --    | 25    | --   | --   | --  | 6.66  | --   | --   |
| 10 | Kori et al <sup>26</sup>           | 2015 | 600  | 73.9                     | 58.8  | 15.1  | 21.5  | 9    | 11.3 | 1.2 | 3.6   | 0.3  | 0.6  |
| 11 | Kullar J S et al <sup>16</sup>     | 2015 | 200  | 72.5                     | 30.0  | 42.5  | 25.5  | 10.5 | 15   | --  | 1.5   | 1.5  | --   |
| 13 | Rajshree et al <sup>27</sup>       | 2016 | 45   | 66.6                     | --    | --    | 31.3  | --   | --   | --  | --    | --   | 2.2  |
| 14 | Present study                      | 2017 | 50   | 66                       | 36    | 30    | 20    | 4    | 10   | 6   | 4     | 10   | --   |

In the present study, the type I calcanei was the most common (66%) and the observation was in consonance with previous studies where mostly the figures ranged between 54.0-59.5%. However, Koriet al<sup>25</sup> reported the incidence of type I calcanei somewhat higher (73.9%). Bunning and Barnett<sup>12</sup> has reported the incidence of type I calcanei only 33%.

Further, in type I, two subtypes were found i.e. constricted (cn) and not constricted (NC). Type I (cn) was observed in 36% cases. However these figures described by other workers i.e. Jha and Singh<sup>13</sup> - 33.75%, Campos and Pellico<sup>17</sup>-29% and Koriet al<sup>26</sup>-58.8%. Type (NC) was observed in 33% cases.

The incidence of type II calcanei was 20% in the present study and this figure is comparable with the work of Koriet al<sup>26</sup> who gave the incidence as 21.5%. However much higher figures have been reported by some workers i.e. 67% by Bunning and Barnett.<sup>12</sup>

Further, in type II, three subtypes were found i.e. A, B and C. Type II (A) was found to be present in 4% cases, Type II (B) in 14% cases and Type II (C) in 8% cases which on comparison do not coincide with the Campos and Pellico,<sup>17</sup> Saddeh et al,<sup>15</sup> Kori et al<sup>26</sup> and Kullar J S et al.<sup>16</sup>

In the present study, the incidence of type III calcanei was 2% in 4 cases. It was highest 18.85% in studies of Drayer-Verhagen<sup>18</sup> followed by Chavanet al<sup>25</sup> (6.66%). In other studies it ranged between 1.3%-5.52%.

The incidence of type IV calcanei in the present study was very high i.e. 5%. However, much low figures have been reported by some workers i.e. 0.12% by Jha and Singh.<sup>13</sup>

The results of the present study showed a wide range of variations in the incidences of various types of calcanei compared to previous workers. These variations may be due to population differences, type of gait and built of an individual or the place of living whether it is plane or hilly area.

## Conclusion

The individual and racial differences of the anatomic construction of calcaneal talar articular facets influence the static and kinetic dynamics of foot. A thorough knowledge of calcaneal facet type and shape is important for all surgeries in subtalar region, better treatment and management options for calcaneal fractures.

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