

## **Anatomical Variations of the Articular Surfaces of the Calcaneus among Bulgarian Population**

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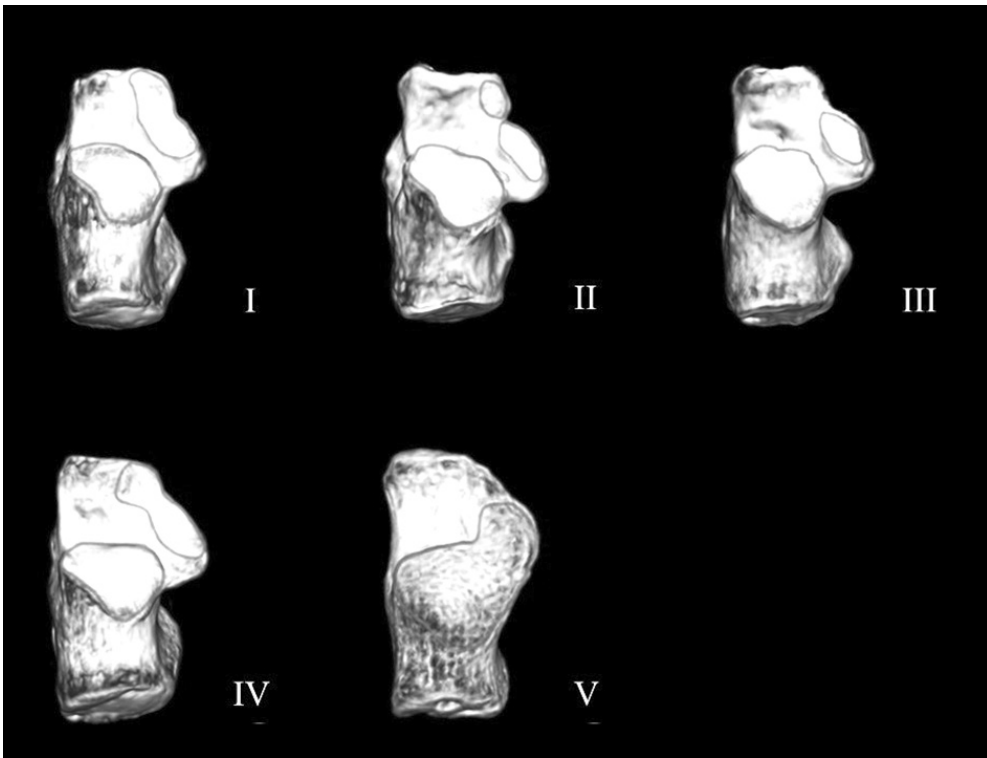
The subtalar joint is formed between talus and calcaneus, has a major role in redistributing the body weight to the distal parts of the foot. Our study showed that the variants with fused anterior and middle facets were widespread among the Bulgarian population. We measured the Gissane's angle, formed between the planes of the anterior and posterior articular surfaces of the calcaneus. The type with three separate articular surfaces was the most common and the angle was the smallest and sharpest. Next in frequency was the variant with fused anterior and middle facets which formed a hourglass shaped surface. On the third place was a spindle-shaped facet, formed by fusion of the anterior and middle ones and the Gissane's angle was the greatest one. In all these variants, the posterior facet of the calcaneus was autonomous and separated from the others.

*Key words:* calcaneus, articular surfaces, Gissane's angle, subtalar joint.

### **Introduction**

Two anatomically and spatially separate joints are formed between the talus and the calcaneus - art. subtalaris and art. talocalcaneonavicularis by anatomical nomenclature. Because these two joints are functionally linked in a single kinematic chain, it is customary to collectively refer to them as the subtalar joint. This joint has a major role in redistributing the weight of the body to the distal parts of the foot. The anterior and middle articular surfaces of the calcaneus are accepted as part of the medial arch, and the posterior – as part of the lateral arch of the foot. Thus, the anatomy of this joint and its articular facets influence the overall morphology of the foot [6]. According to literature, several different variants of talar articular facets have been described [1, 11]. In type I, the anterior and middle articular surfaces of the calcaneus are fused and the resulting surface is spindle-shaped, remaining separated from the posterior one. Type II is distinguished by three different articular surfaces. The third variant (type III) is characterized by missing anterior facet, and the middle and posterior articular surfaces

are separated from each other. In type IV, the anterior and middle facets are fused, but the resulting surface is hourglass shaped. Type V presents with missing anterior and fused medial and posterior articular surfaces [1, 11] (**Fig.1**).



**Fig. 1.** Types of the talar articular facets of the calcaneus. The articular facets are outlined. Type I – fused anterior and middle facets in an oval-shaped articular surface. Type II – three separated articular surfaces. Type III – a missing anterior articular facet. Type IV – fused anterior and middle facets in an hourglass shaped articular surface. Type V – a missing articular facet and fused middle and posterior articular ones. (Agarwal et al., 2016 – [1]).

Bunning and Barnett have found a significantly higher frequency of the calcaneus type with three separate, autonomous facets, described as Type II by Agarwel, in the European population [3]. In their study significant differences were also indicated in the morphology of the calcaneus in the populations in Europe, Africa and Asia. According to their data, the type with the highest incidence among non-Europeans was that with fused anterior and middle articular surfaces, and its frequency was particularly high in women in African and Asian race. In study of the population in India, fusion of the anterior and middle surfaces has been observed in more than 66% of the examined calcanei. The next most frequent variation, with three separate facets, has been presented in 27.5% of cases [1]. Similar data has been obtained in a study in Turkey, where type I and type IV were dominant, with a total frequency of 58% [10].

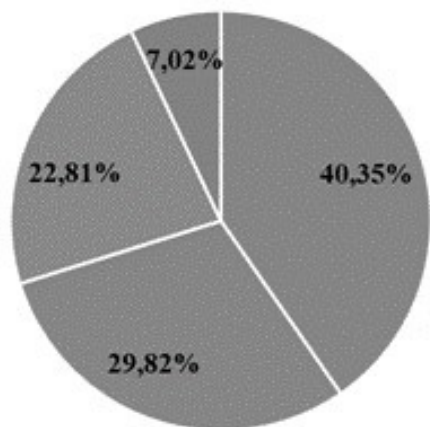
## Materials and methods

The present study was conducted on 130 calcanei from the bone collection of the Department of Anatomy and Cell Biology of MU-Varna. The bones belonged to Bulgarian citizens and were prepared by maceration according to the department's protocol. The obtained dry specimens were photographed, and the Gissane's angle was measured using open source software ImageJ. The Gissane's angle was defined as the angle between the planes of the anterior and posterior articular surfaces of the calcaneus. The results were statistically processed using Excel.

## Results

The conducted study on the calcanei from the collection of bones in MU-Varna showed that the variants with fused anterior and middle facets were widespread among the Bulgarian population.

The type with three separate articular surfaces (Type II by Agarwel) was the most common and represented 40.35% of the studied bones. Next in frequency was the variant with fused anterior and middle facets which formed an hourglass shaped surface (Type IV) and it was observed in 29.82% of the cases. In 22.81%, a spindle-shaped or oval articular surface was found, resulting from the fusion of the anterior and middle ones (Type I). In all three described variants, the posterior facet of the calcaneus was autonomous and separate from the others. An anterior facet was missing in 7.02%, with separate middle and posterior facets (Type III). There were no cases corresponding to type V with fusion of the middle and posterior facets. In addition, the data showed a prevalence of variants with fused anterior and middle articular surfaces, and in total they represent 52.63% of all studied bones (Fig. 2).

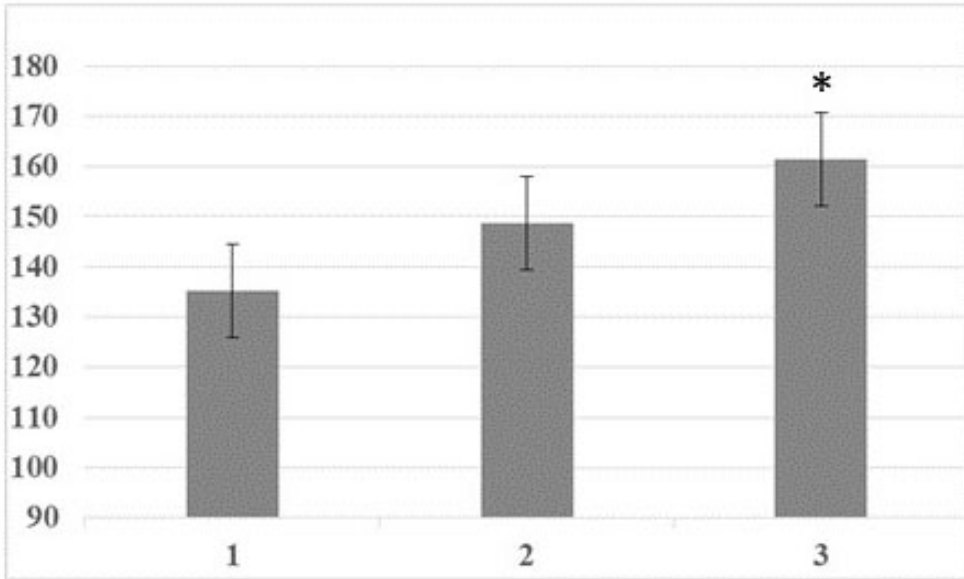


**Fig. 2.** Incidence of the observed types of calcaneus. 40,35% – three separated articular surfaces; 29,82% – fused anterior and middle facets in a hourglass shaped articular surface; 22,81% – fused anterior and middle facets in an oval-shaped articular surface; 7,02% – a missing anterior articular facet and fused middle and posterior ones.

The type I, type II and type IV Gissane's angle was measured (Table 1). The absence of an anterior articular surface in type III was judged to preclude the accurate measurement of the angle. We observed that the angle was the smallest and sharpest in the cases with three different articulation surfaces (Type II). The mean value was  $135.26^\circ$  ( $SD \pm 9.25^\circ$ ). In Type IV it was  $148.76^\circ$  ( $SD \pm 7.79^\circ$ ) and it was the greatest one in Type I –  $161.38^\circ$  ( $SD \pm 6.66^\circ$ ). The difference of the value Gissane's angle of these three groups was statistically significant ( $p \leq 0.05$ ) (Fig. 3).

**Table 1.** Comparison of the Gissane’s angle measurements. The angle values are presented in degrees (mean value ± SD).

Variants of talar articular facets	Type I	Type II	Type IV
Gissan’s angle	161.38°± 6.66°	135.26°± 9.25°	148.76°± 7.79 °



**Fig. 3.** Gissane’s angle in different types of calcaneus in our study. 1 – three separated articular surfaces; 2 – fused anterior and middle facets in an hourglass shaped articular surface; 3 – fused anterior and middle facets in an oval-shaped articular surface.

## Discussion

Variations in the articular surfaces between the calcaneus and talus have shown racial and regional differences. They affect mobility in the subtalar joint [2]. The joint is significantly more stable in the presence of three separate facets because in this situation they form a kind of tripod on which the talus is located and prevent excessive movement of its head. The study of Meary’s angle (between the axis of the first metatarsal bone and the central axis of the talus) has proved a significant statistical difference in the incidence of flat foot in type I and type IV calcaneus compared to type II. This is in an agreement with the values of Gissane’s angle, which are greater in types with fused facets. As larger is the angle, as flatter is the superior surface involved in the subtalar joint. The most obtuse angle has been observed in the cases when the fusion of anterior and middle facets results in an oval-shaped anterior surface [1, 9]. Our results are in unison with the available literature data.

In the cases with fused anterior and middle articular surfaces, the mobility of the subtalar joint is increased, especially the range of rotation of the talar head. It can lead to overstretching of the plantar calcaneonavicular ligament and adjacent muscle tendons, due to their continuous overload. Over time, this type of subtalar joint is predisposed to the development of joint instability and osteoarthritic changes [5] and has been associated with the development of flat foot [2].

In the cases with absence of the anterior articular surface, but middle and posterior one are on their appropriate places, the sustentaculum tali does not provide adequate support for the superiorly located talus. The talar head overrotates anteriorly and inferiorly, with the talus tilting plantarly and the calcaneus in a valgus position. Increased pressure on the anterior part of the subtalar joint, laxity of the capsule and ligaments, and frequent association with flat feet have been reported [8].

The major role of the subtalar joint in the integrity of the foot arches has led to the development of variety of techniques and methods that remodelate foot biomechanics, altering joint morphology. Increased height of the medial foot arch with at least five millimeters after subtalar arthrodesis has been reported [7]. At the same time, variations in the articular surfaces can affect the outcome of operative interventions, such as lateral calcaneus lengthening osteotomy [4].

## Conclusions

1. There are three most frequent types of articular surfaces of the calcaneus among the Bulgarian population.
2. The most common type of the articular surfaces of the calcaneus among the Bulgarian population is with three separate articular facets (Type II by Agarwel), but the majority of cases are with fused anterior and middle facets.
3. Gissane's angle correlates with the type of articular surfaces of the calcaneus.

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