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Implications of Classification of Os Trigonum: A Study Based on Computed Tomography Three- Dimensional Imaging

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Background: The os trigonum is an accessory bone that is not fully fused with the talus during secondary ossification, and is one of the risk factors of posterior malleolus impact syndrome. The purpose of this study was to classify the os trigonum and to guide the diagnosis and treatment of related clinical diseases.


Material/Methods: Ankle computed tomography (CT) scans of 586 Chinese patients between October 2014 and October 2018 were reviewed. CT images of 1011 ankle joints were reconstructed to evaluate the classification of the os trigonum and the measurement of anatomical parameters.

Results: The incidences of os trigonum in 3 groups were determined as type I (1.9%), type II (10.5%), and type III (14.7%). The macro-axis of type II (0.89 ± 0.31 cm) was significantly larger than with type I (0.65 ± 0.24 cm) and type III (0.74 ± 0.23 cm) ($p < 0.05$). The minor axis of similar of type I (0.41 ± 0.23 cm) was significantly shorter than that of type II (0.58 ± 0.32 cm) and type III (0.55 ± 0.16 cm) ($p < 0.05$). The distance from os trigonum to calcaneal tubercle was significantly different than that of type I (1.33 ± 0.52 cm), type II (1.67 ± 0.55 cm), and type III (1.84 ± 0.45 cm) ($p < 0.05$).

Conclusions: This study showed that os trigonum has a high incidence. Type I was the least common, the volume of type II was larger, and type III was more common. The anatomical parameters of each type may improve treatment of related diseases and the further development of ankle arthroscopic surgery.

MeSH Keywords: Ankle • Models, Anatomic • Talus

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Background

Os trigonum of the talus usually refers to an accessory bone that is not fully fused with the talus in secondary ossification and is still connected with the lateral tubercle of the posterior process of the talus through cartilage [1]. Os trigonum is often considered an accidental radiologic discovery that generally does not cause pain. However, long-term torsion and compression lead to acute injury of articular cartilage, resulting in cartilage edema and thickening aseptic inflammation [2,3]. Single or repeated forced plantar flexion can lead to degeneration or tearing of articular cartilage. Repeated impacts on the posterior triangular bone of the adjacent soft tissue may cause pain in the posterior side of the ankle and swelling around the triangular bone [4,5]. The fracture of the posterior process of talus and the fracture of the posterior triangle of the talus are easy to be confused clinically, and computed tomography (CT) scans and magnetic resonance imaging can detect the associated bone and soft tissue abnormalities, thus complementing each other [6,7].

The fracture of the neck of talus cannot be separated from the internal fixation of the tunnel established by the lateral tubercle of the posterior process of the talus [4]. The flexor hallucis longus muscle tendon is located between the medial and lateral tubercle of talus posterior protrusion, and the os trigonum acts as the attachment point of the posterior talo-fibular ligament, while the sural nerve and the calcaneal tendon are located in the posterior side of the ankle [8–10]. The different connection modes of the os trigonum affect the morphological parameters and the selection of treatment methods.

In 1804, the small bone on the posterior side of the talus was described for the first time by Rosenmuller. In the 1860s, it emerged that the secondary ossification center of the os trigonum, which was secondary to the talus, was not fully fused with the talus body. In 1885, Bardeleben used the term “os trigonum” for the ossicle, replacing the term “os intermedium tarsi”. In 1996, Zhizhong Zhao and others studied the relationship between the existence and size of the os trigonum and the size of the tibial Achilles tendon angle, emphasizing that posterior malleolus pain was obvious when the triangular bone was larger than 5 cm. In 2017, Ruben Zwiers classified os trigonum according to the position relationship between the os trigonum and the posterior of the talus, and they were compared among different ethnic groups [11–13].

However, since the first descriptions of os trigonum, there has been no consensus about its morphological parameters, and type studies were rare [14]. The aim of this study was to obtain types of os trigonum and more detailed morphological parameters in Chinese patients to assist doctors in the diagnosis and treatment of related diseases and reduce tendon and nerve

injury during surgery [15–17]. In addition, the main contribution of this study is showing the similarity between the prominent lateral tubercle of posterior talar process (Stieda's process) and the os trigonum in origin, location, and clinical diseases. For the first time, Stieda's process was also classified into the os trigonum and classified according to the mode of connection, and the anatomical parameters were measured. These findings may help future research and development of ankle arthroscopy.

Material and Methods

Ethical statement

This study was approved by the Ethics Committee of the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (KY2018012).

Materials

Ankle computed tomography (CT) scans taken between October 2014 and October 2018 in the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University were reviewed. Axial slices of all bilateral and unilateral ankles were included. Symptoms, indication for CT scan, and past history were obtained from the medical records. Patients who had injuries or fractures to their ankles before admission and extensive ankle deformation (rheumatoid arthritis or congenital malformations) were excluded. In addition, patients who underwent hindfoot surgery prior to the CT scans were also excluded.

Taking into account the subject of the study and the overall impact of the sample data volume on the accuracy of the study, a total of 586 Chinese patients (345 males, 241 females; mean age 50 years; age range 15–85 years) were selected, including 161 patients who were only given unilateral ankle examination during hospitalization. When patients had multiple CT scans, the first scan was included in this study.

All scans met the requirements of CT three-dimensional reconstruction. The CT scans were reconstructed and measured by the Picture Archiving and Communication Systems (PACS) to assess the presence, type, and relevant anatomical parameters of os trigonum.

Methods for os trigonum classification

Os trigonum was identified as 3 basic types based on the mode of connection: Type I was a single piece of bone that was not connected to the talus, Type II was connected to the posterior talar process by a hyaline cartilage layer, Type III was the Stieda's process (i.e., the part of the sagittal plane extending beyond the extension line of the lower tibia (Figure 1).

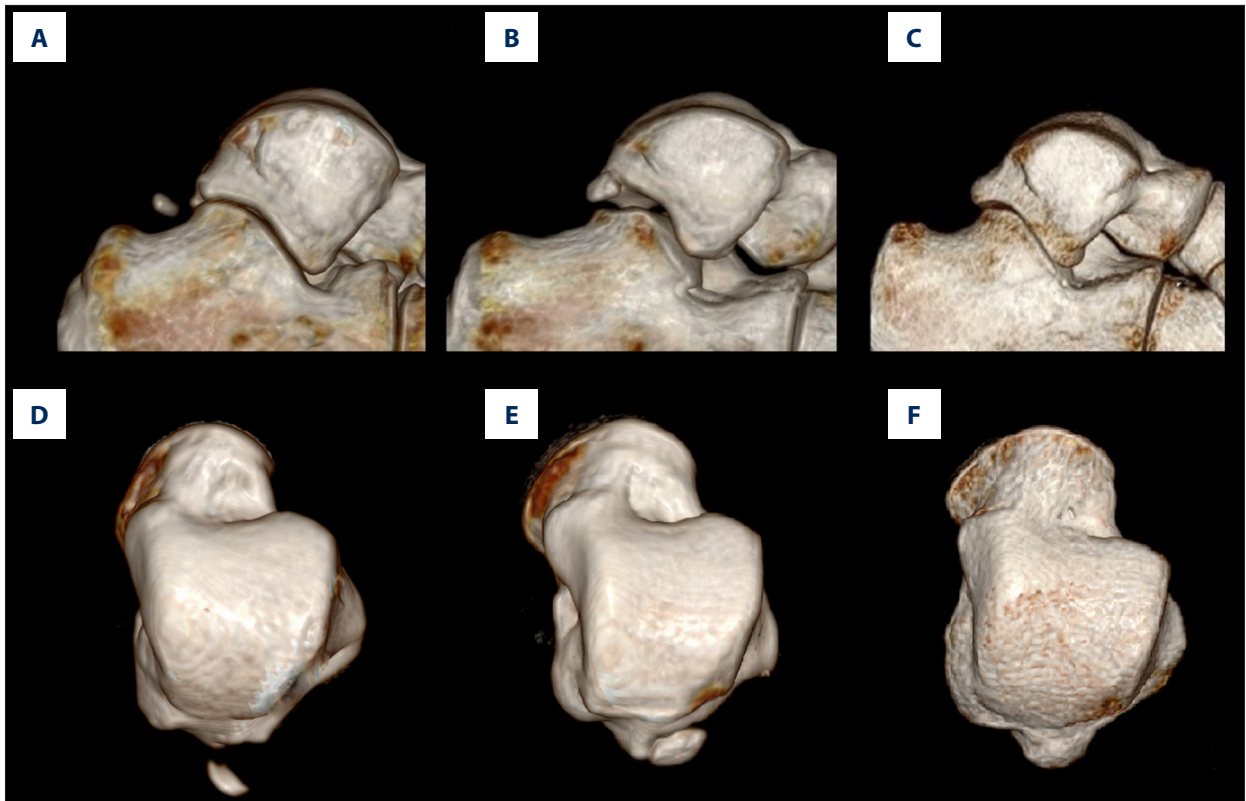


Figure 1. CT three-dimensional image of the os trigonum. Sagittal position of os trigonum. (A) Type I; (B) Type II; (C) Type III. Horizontal position of os trigonum. (D) Type I; (E) Type II; (F) Type III.

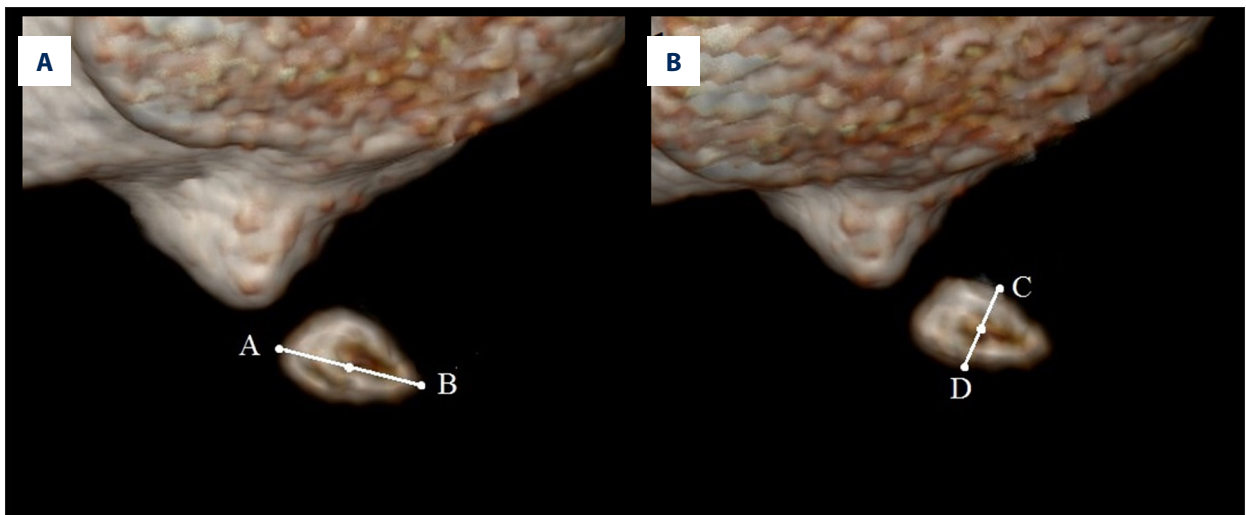


Figure 2. Morphometric measurements. (A) AB: the macro-axis of the os trigonum. (B) CD: the minor-axis of the os trigonum.

Methods for measuring the morphological parameters

AB, the macro-axis of the os trigonum from A to B (Figure 2).

CD, the minor-axis of the os trigonum from C to D (Figure 2).

Point E, the vertical intersection between the central axis of the tibia and the central axis of the os trigonum, it was the origin.

Point F, the center point of the os trigonum.

Point G, the lowest point in the lower tibia.

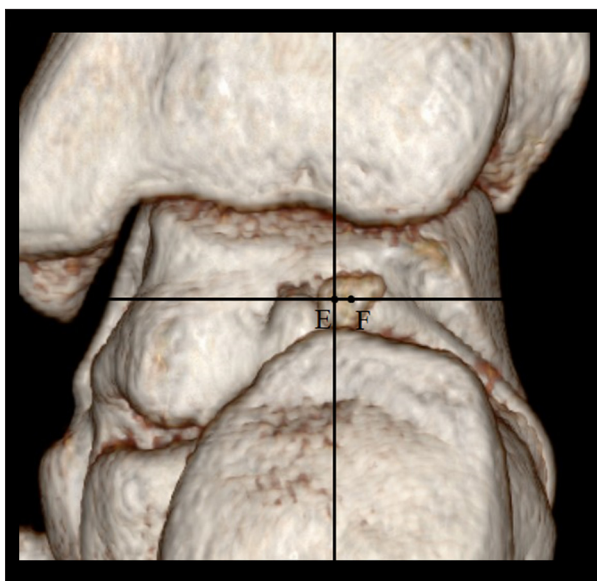


Figure 3. Morphometric measurements. Point F, the center point of the os trigonum. Point E, the vertical intersection between the central axis of the tibia and the central axis of the os trigonum, which was the origin. EF, the distance from the os trigonum to the central axis of the tibia; the origin is negative on the left and positive on the right.

Point H, the highest point of the superior margin of the os trigonum.

Point I, the most posterior point of the os trigonum.

Point J, the most anterior point of the calcaneal tubercle.

EF, the distance from the os trigonum to the central axis of the tibia (the origin is negative on the left and positive on the right) (Figure 3).

GH, the distance from the superior margin of the os trigonum to the lower margin of the tibia (Figure 4).

IJ, the distance from posterior margin of os trigonum to the calcaneal tubercle (Figure 4).

Statistical methods

All data were analyzed by IBM SPSS 21.0 statistical software. The homogeneity of variance was performed by using the Kolmogorov-Smirnov test. One-way ANOVA was used to compare 3 types of os trigonum, considering a P value <0.05 as statistically significant. All the measurements are expressed as mean ± standard deviation (SD), and the incidence of each type is described by numbers and percentages.

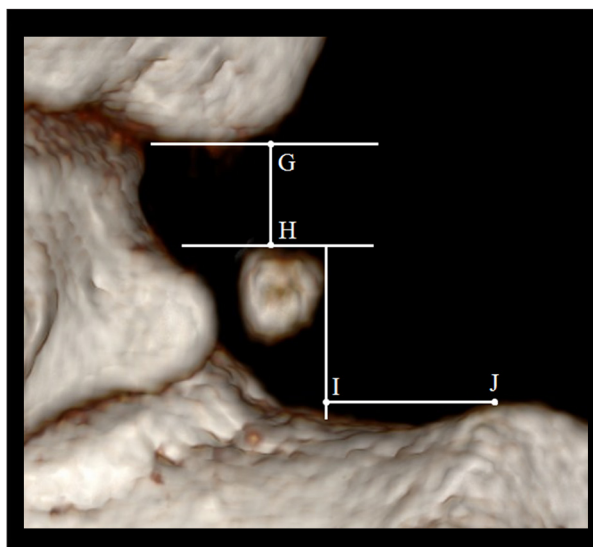


Figure 4. Morphometric measurements. Point G, the lowest point in the lower tibia. Point H, the highest point of the superior margin of the os trigonum. Point I, the most posterior point of the os trigonum. Point J, the most anterior point of calcaneal tubercle. GH, the distance from the superior margin of the os trigonum to the lower margin of the tibia. IJ, the distance from posterior margin of os trigonum to calcaneal tubercle.

Results

A total of 1011 ankle joints were observed in this study, of which 275 cases were os trigonum, and the incidence rate was 27.2%. These bones were seen in 77 female participants and 136 male participants. Os trigonum were classified into 3 groups – type I, type II, and type III – and the incidence of these bones were 1.9%, 10.5%, and 14.7%, respectively (Table 1).

Anatomical parameter measurement

AB: the type II (0.89 ± 0.31 cm) was significantly larger than type I (0.65 ± 0.24 cm) and type III (0.74 ± 0.23 cm) ($p < 0.05$).

CD: the type I (0.41 ± 0.23 cm) was significantly shorter than that of type II (0.58 ± 0.32 cm) and type III (0.55 ± 0.16 cm) ($p < 0.05$).

EF: the type I (0.05 ± 0.26 cm) was located on the right side of the axis, type II (-0.02 ± 0.19 cm) was found on the left side, type III (0 ± 0.25 cm) was more evenly distributed on both sides of the axis ($p > 0.05$).

GH: the type I (0.70 ± 0.38 cm), type II (0.61 ± 0.28 cm) and type III (0.58 ± 0.22 cm), and there was no significant difference ($p > 0.05$).

IJ: the type I (1.33 ± 0.52 cm) was the smallest distance, and type III (1.84 ± 0.45 cm) was the largest distance, and the type II

Table 1. Anatomical parameters of os trigonum.

Os trigonum	NO	AB (cm)	CD (cm)	EF (cm)	GH (cm)	IJ (cm)
Type I	20 (1.9%)	0.65±0.24 ^b	0.41±0.23 ^{b,c}	0.05±0.26	0.70±0.38	1.33±0.52 ^{b,c}
Type II	106 (10.5%)	0.89±0.31 ^{a,c}	0.58±0.32 ^a	-0.02±0.19	0.61±0.28	1.67±0.55 ^{a,c}
Type III	149 (14.7%)	0.74±0.23 ^b	0.55±0.16 ^a	0±0.25	0.58±0.22	1.84±0.45 ^{a,b}

^a p<0.05 vs. Type I; ^b p<0.05 vs. Type II; ^c p<0.05 vs. Type III. NO – number and incidence percentage of each type of os trigonum; AB – the macro axis of the os trigonum; CD – the minor axis of the os trigonum; EF – location of os trigonum under the central axis of the tibia; GH – distance from the os trigonum to the lower tibia; IJ – distance from posterior margin of os trigonum to calcaneal tubercle.

(1.67±0.55 cm) distance was between the other 2 types. There were significant differences among the 3 types (p<0.05).

Discussion

In this study, the incidence of os trigonum was 27.2%, but the incidence in the general population has been reported to be 1–25% [18], probably because the Stieda's process was classified as a type of os trigonum. In our results, the incidence of type I was 1.9%. In addition, type I was smaller, farther from the lower tibia, and closer to the calcaneal tubercle, which may be because the relationship with the talus was not as close as with other types.

The size of type II was usually larger, which was very significant in the manifestation of the macro- and minor-axis. In some studies of athletes or dancers, the appearance of the impacted bone and the thickening of the soft tissue caused by the attachment nodule were the main causes of pain. Because posterior calf impact syndrome is closely related to the change of fibrous cartilage, it was also a major type of pain, and the incidence of type II was higher, at about 10.5% [19]. According to the literature, although the separation line between the type II os trigonum and the adjacent bone was generally smoother than the actual avulsion line, the soft tissue could not be clearly seen on the X-ray, which made it difficult to distinguish the fracture from the os trigonum [20]. That was the main reason for separating type II based on the connection method, suggesting that physicians should focus more on the problem of soft tissue connections in the hope of improving diagnostic rates. Deltoidectomy has been a common clinical method for the posterior malleolus impact syndrome, and the measurement of anatomical parameters was of great significance to the choice of both the amount of osteotomy and the mode of entering [21,22].

In this study, the incidence of type III os trigonum was the highest among all types, and in a study of ballet dancers, the incidence rate of type III reached 44% [5,6,19,23], perhaps due

to dancing from an early age, the development of os trigonum was affected. There was the pain in type III os trigonum, which was mostly caused by the thickening of the posterior capsule of ankle joint caused by impacted tenosynovitis of pollicis longus muscle and edema of soft tissue around it [18,24]. In the case of fracture of the neck of the talus, type III os trigonum could be used for the posterior approach screw implantation and internal fixation [7,12]. The measurement of the macro- and minor-axis, position relationship, and distance as the point of entry provided the basis for estimating the diameter of the bone tunnel and the length of screw [25–28], and it was more suitable for the general public.

In conclusion, 3 types of os trigonum were studied in detail and their incidence was studied. The measurement of anatomical parameters also provides some enlightenment for further research, which would be beneficial to the diagnosis and treatment of related diseases and the development of ankle arthroscopy.

The current study has several limitations. The study was based on a large sample volume and explored the differences between different types of os trigonum. We did not include differences in fractal patterns caused by morphological analysis of measurement, which may have affected the results, and further research is needed to confirm our results.

Because some patients may have posterior impact without obvious clinical manifestation, future studies could compare patients with posterior impact and those without posterior impact.

Conclusions

The os trigonum of many specimens in China was classified and measured. The results showed that the incidence of os trigonum is high. In the study of classification, type III was the most common, and type I was the least common. Type II was larger in the 3 types and the difference between the macro- and minor-axis was the most significant compared with the

other types. The parameters provided in this paper will benefit treatment of posterior malleolus impingement syndrome, and our results provide an anatomical basis for the further development of ankle arthroscopy.

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Conflict of interests

None.