In Different Gender Groups, What Is the Impact of the Fibular Notch on The Severity of High Ankle Sprain: A Retrospective Study of 240 Cases

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Research Article

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Abstract

Background: The function of the distal tibiofibular ligament on the ankle in the occurrence of high ankle sprain (HAS) has been widely studied. Then, in different genders, the effect of the anatomical morphology of fibular notch (FN) on HAS is unclear. Therefore, on the basis of excluding the anatomical differences caused by gender, we explore the impact of different types of FN on the severity of HAS.

Methods: We selected 120 patients and further classified these 120 patients into four HAS groups according to FN depth with deep concave type FN ≥ four mm and shallow flat type FN < four mm. A further 120 normal individuals were served as a control group. FN morphological indicators, tibiofibular distance (TFD), and ankle mortise indexes were measured and compared between patients and control groups.

Results: In males with shallow flat type, the Anterior tibiofibular distance (aTFD), Middle tibiofibular distance (mTFD), Posterior tibiofibular distance (pTFD), Front tibial width (FTiW), Middle tibial width (MTiW), Posterior tibial width (PTiW) and Depth of ankle mortise (DOAM) of HAS group were higher than those in normal group ($P < 0.05$). In males with deep concave type, the aTFD, mTFD and DOAM of patients were significantly higher ($P < 0.05$).

Among females with shallow flat type, the aTFD, mTFD, pTFD, FTiW and MTiW in HAS group were greater than those in normal group ($P < 0.05$). Among the females with deep concave type, the mTFD and pTFD of patients were higher ($P < 0.05$).

Conclusions: After analyzing the morphological indicators of FN, it is found that in both males and females, HAS patients have significant differences in TFD and certain ankle mortise indexes compared with normal people. But more importantly, the above abnormalities are often more common in HAS patients with shallow flat FN, indicating that shallow flat FN may be related to more serious distal tibiofibular ligament injury and ankle mortise widening, resulting in a worse prognosis.

Level of evidence: Level III, retrospective comparative study.

Background

High ankle sprain (HAS) is a serious injury which can be almost three to four times severe than lateral ankle sprain and medial ankle sprain [1–3]. The study found that regardless of the initial grade of injury severity, patients with HAS have a higher incidence (over 60%) of chronic ankle pain, instability, and hopping restriction when evaluated within six months after injury [4]. The high ankle ligaments (also called the syndesmosis) are on the ankle, opposite the more commonly injured ligaments on the outside of the ankle. These ligaments are located around the distal ends of tibia and fibula, so syndesmotic sprain or high ankle sprain is a type of distal tibiofibular syndesmosis injury that may have a rupture of the distal tibiofibular ligaments and interosseous membrane [5–8]. In addition to the ligament complex composed of the anterior distal tibiofibular ligament, posterior distal tibiofibular ligament, transverse ligament, and interosseous ligament, which provides distal tibiofibular joint (DTFJ) with extrinsic stability, the fibular notch (FN), as an endogenous stabilizer, also has an important impact on the occurrence of HAS [9].

The distal tibiofibular syndesmosis includes the distal ends of distal tibia and fibula and the distal tibiofibular syndesmosis ligament complex. The FN is located slightly behind the lateral side of the lower tibia, and the distal fibula is located in the FN of the tibia, forming a DTFJ with the distal tibia, which is defined as the lower joint without articular cartilage [10]. Although its amount of movement is very small, it has a very important impact on the movement of the ankle [10]. FN is an important anatomical structure in the distal tibiofibular syndesmosis, and there are extensive variations in the population [11, 12]. Previous studies have confirmed that FN is a consistent index to evaluate the stability of syndesmotic [13–15]. Moreover, some anatomical configurations of FN are related to the increased risk of specific syndesmotic mal-reduction patterns, such as anteversion of the incisura correlated with anterior displacement of the fibula, while retroversion of the incisura correlated with posterior fibular displacement [16]. The concave and convex surfaces formed by the tibia and fibula correspond to each other and are located at the same level. Therefore, patients with shallow flat FN are prone to ankle injury [17]. According to Ebraheim, in the study of 100 patients, 67% of the patients had deeper FN (crescent shape) and 33% were shallower (rectangle), suggesting that the depth of FN may affect the stability of the distal tibiofibular syndesmosis [17]. The shallower FN is associated with recurrent ankle sprains, and in the study of Liu et al., the FN was further divided into three types, namely C-shaped (56%), 1-shaped (25%) and Γ-shape (19%)[18, 19]. The results of the study showed that participants whose FN shape resembled the number "1" had the widest range of displacement in the distal tibiofibular syndesmosis on the Y axis, and had the highest risk of recurrent lateral ankle joint sprains [18]. Huysse et al. converted CT images into three-dimensional models for measurement, and then found that the FN of HAS patients was shallower and shorter than that of normal people by comparing FN width, depth and other parameters, and such morphology would affect the syndesmotic stability [20].

There are few studies on the impact of gender differences on HAS, but a few studies report that the degree of injury in male is greater than that in female [2, 21]. At the same time, the measurement of FN will be affected by gender, which may be due to the morphological differences between tibia and fibula [15]. Therefore, based on the imaging data of axial CT, we analyzed the FN and HAS related to parameters of HAS patients of different genders the influence of FN on HAS on the basis of excluding the anatomical differences caused by gender.

Materials And Methods

Ethical statement

Our study is a retrospective study and the approval of our study was granted by the Ethical Committee of The Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (No. KY2018043).

We can access the patient's relevant data with the consent of the Ethical Committee of The Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University.

Subjects

A total of 120 people with average age of 43 years (range, 18-80) met the inclusion criteria (60 males, 60 females), including Chinese foot with varying severity of HAS.

Inclusion criteria: (1) Complete development of distal tibiofibular syndesmosis; (2) Diagnosed as HAS or injury;(3) No history of major systemic disease, degenerative disease, fracture, or surgery involving the ankle;(4) Tolerable to CT examination;(5) The imaging data and other basic information of patients are complete. All patients were screened by medical practitioners and met the above inclusion criteria.

The Morphological Parameters of Measurement

FN: The following parameters are measured 10mm above the tibial plafond (Figure1).

FN Depth: Distance from the deepest point at the FN to the nearest point on the tangent between the tip of the anterior tibial tubercle and the tip of the posterior tibial tubercle. FN is divided into two types according to the depth: shallow flat type for those less than four mm and deep concave type for those ≥ four mm.

Tibiofibular distance (TFD):

Anterior tibiofibular distance (aTFD): the distance between anterior border of the fibula and the nearest perpendicular point from anterior border of the fibula on anterior tibial tubercle.

Middle tibiofibular distance (mTFD): the distance between the deepest point at the incisura to the nearest point from deepest point at the incisura on the fibula.

Posterior tibiofibular distance (pTFD): the distance between the medial border of the fibula and the nearest perpendicular point from the medial border of the fibula on the lateral border of the posterior tibial tubercle.

Ankle mortise indexes

Depth of ankle mortise (DOAM): The distance between the anterior and posterior malleolus in the sagittal plane (Figure 2).

The following parameters were measured in the tangential plane to both dome of the talus.

Tibial width (TiW):

Front tibial width (FTiW): Draw a tangent line (a) of medial malleolus through point A and a tangent line (b) of lateral malleolus through point B; Draw a tangent of tibia parallel to AB and intersect with tangents a and b at two points C and D, and CD is FTiW.

Middle tibial width (MTiW): between the middle points of the medial (point A) and lateral malleoli (point B) at the level of the talar dome.

Posterior tibial width (PTiW): Draw a tangent line of the posterior ankle parallel to AB, intersect with tangent lines a and b at two points E and F, and EF is the PTiW.

Statistical Methods

All measurements were expressed as mean and standard deviation (SD). Measurements (FN depth, aTFD, mTFD, pTFD, FTiW, MTiW, PTiW and DOAM) were compared by independent t test, considering a $P < 0.05$ as statistically significant. SPSS version 25.0(IBM, New York, USA) was used for all statistical analysis.

Results

We selected 120 patients according to the inclusion and exclusion criteria, 60 each for men and women. We divided 120 patients into four groups according to the depth of FN, in which males and females were each divided into two groups (30 each), with FN ≥ four mm as deep concave type and FN < four mm as shallow flat type (Figure1). A further 120 normal individuals were included, similarly grouped according to the above method and serving as a control group. There was no significant statistical difference in age between all HAS and normal groups.

An independent t-test showed significant differences in the aTFD (4.52 ± 2.60 vs 3.58 ± 1.32mm), mTFD (4.62 ± 2.26 vs 3.09 ± 0.91mm), and pTFD (8.24 ± 3.91 vs 8.24 ± 3.91mm) between the HAS group and the control group who were equally shallow flat type in males, and the HAS group was larger than the normal group ($P < 0.05$) (Table1). HAS patients with shallow flat type FN had significantly larger FTiW (36.06 ± 3.79 vs 34.23 ± 2.43 mm), MTiW (34.00 ± 3.17 vs 32.28 ± 2.06 mm), and PTiW (31.85 ± 3.42 vs 30.49 ± 2.09 mm) as well as DOAM (20.32 ± 2.73 vs 18.91 ± 2.10 mm) than the normal population ($P < 0.05$) (Table1). In males with the deep concave type, aTFD (4.72 ± 3.21 vs 2.71 ± 0.90 mm) and mTFD (4.88 ± 2.49 vs 3.39 ± 0.97 mm) of the patients were significantly greater than the normal subjects ($P < 0.05$), but among the ankle mortise indexes, only the ankle DOAM (22.86 ± 4.33 vs 19.86 ± 2.46 mm) was statistically different and greater in the HAS group than the control group (Table1).

Significant differences were found in the aTFD (4.12 ± 3.42 vs 2.79 ± 1.38 mm), mTFD (3.80 ± 2.43 vs 2.46 ± 0.83 mm), and pTFD (7.37 ± 2.54 vs 5.76 ± 2.03 mm) between the HAS group and the control group with shallow flat type in females, and the HAS group was larger than the normal group ($P < 0.05$) (Table2). The FTiW (32.08 ± 3.02 vs 30.59 ± 2.39 mm) and MTiW (30.29 ± 2.48 vs 29.11 ± 2.23 mm) were significantly larger in HAS patients with shallow flat type FN than in the normal population ($P < 0.05$) (Table2). In females with the deep concave type, the mTFD (4.03 ± 1.79 vs 2.96 ± 0.74 mm) and pTFD (5.38 ± 2.05 vs 4.29 ± 1.36 mm) of the patients were significantly greater than the normal subjects

(P < 0.05), but there was no statistical difference between the HAS group and the control group in any of our measured ankle mortise indexes (Table2).

Table1. The Morphological Measurement Parameters of Males

	aTFD	mTFD	pTFD	FTiW	MTiW	PTiW	DOAM
Shallow							
HAS	4.52±2.60	4.62±2.26	8.24±3.91	36.06±3.79	34.00±3.17	31.85±3.42	20.32±2.73
Control	3.58±1.32	3.09±0.91	6.89±1.90	34.23±2.43	32.28±2.06	30.49±2.09	18.91±2.10
p-Value*	0.037	<0.001	0.045	0.011	0.005	0.032	0.011
Deep							
HAS	4.72±3.21	4.88±2.49	6.11±2.34	35.91±3.95	33.70±3.68	29.36±9.46	22.86±4.33
Control	2.71±0.90	3.39±0.97	5.76±1.31	34.72±2.73	31.82±5.86	30.67±2.81	19.86±2.46
p-Value	0.005	0.009	0.508	0.191	0.181	0.523	0.005

Measurements presented as mean and SD.

*The differences between the HAS group and the control group compared by independent t test.

Table2. The Morphological Measurement Parameters of Females

	aTFD	mTFD	pTFD	FTiW	MTiW	PTiW	DOAM
Shallow							
HAS	4.12±3.42	3.80±2.43	7.37±2.54	32.08±3.02	30.29±2.48	28.34±2.61	18.90±3.32
Control	2.79±1.38	2.46±0.83	5.76±2.03	30.59±2.39	29.11±2.23	28.04±2.17	18.34±1.19
p-Value*	0.045	0.005	0.006	0.03	0.048	0.615	0.413
Deep							
HAS	3.49±1.45	4.03±1.79	5.38±2.05	33.08±4.16	29.99±2.93	28.84±2.91	19.35±3.00
Control	3.36±1.14	2.96±0.74	4.29±1.36	29.99±2.27	28.62±2.04	27.52±2.04	18.76±2.01
p-Value	0.741	0.019	0.028	0.005	0.079	0.089	0.409

Measurements presented as mean and SD.

*The differences between the HAS group and the control group compared by independent t test.

Discussion

The shape of the FN, and more specifically its concavity, is completed by a one-two mm thick constant narrow cartilage facet joint surface, which is connected to the opposite facet joint surface of the distal fibula[22]. As an exogenous stable structure of the DTFJ, the morphology of FN has been widely studied. For example, studies have shown that anterior displacement of the fibula be with a shallow flat FN and posterior displacement of fibula with a deep concave FN [23]. Some studies have also included the relationship with lateral ankle sprains as well as the occurrence of HAS, but few have investigated gender as a categorical indicator, leading to the neglect of the role played by gender in the influence of FN on the occurrence and development of HAS [18-20,24]. Therefore, males were first separated from females in our study and then grouped according to FN depth to explore the association of FN morphology with HAS occurrence and severity. Four mm has been widely used as a criterion for delineating FN as deep concave or shallow flat in previous studies on the distal tibiofibular syndesmosis, so FN was classified into two types in our study based on previous studies, specifically, FN ≥ four mm as deep concave and < four mm as shallow flat, which will facilitate the comparison of our findings with similar studies (Figure 1) [12,25].

Our study has revealed significant differences in aTFD, mTFD and pTFD between HAS and control groups of the shallow flat type in males, and the HAS group was larger than the normal group ($P < 0.05$) (Table1). In males with the deep concave type, the aTFD and mTFD of the patients were significantly greater than those of the normal subjects ($P <0.05$). Among the females with the shallow flat type, there were also significant differences in aTFD, mTFD and pTFD between the HAS group and the control group, and the HAS group was greater than the normal group ($P < 0.05$), while among the females with the deep concave type, only mTFD and pTFD were significantly greater than the normal person ($P < 0.05$) (Table2). Differences between males and females may be explained by the anatomical variations between males and females rather than the actual differences in the measured parameters [24,26]. But we focused on both males and females, the abnormal increase of the tibiofibular distance occurred more frequently in patients with shallow flat FN than in those with deep concave FN, which also suggested that shallow flat FN may be associated with more severe impairment of HAS or high ankle ligaments. Ankle stability is maintained by the distal tibiofibular syndesmosis, the medial and lateral malleolus, and their surrounding ligaments [27]. The distal tibiofibular syndesmosis is a micro-moved joint that causes the tibia and fibula to micro-move in a physiologic range and is important in maintaining stability and function of the ankle, with the anterior distal tibiofibular ligament providing 35% stability, the posterior distal tibiofibular ligament providing 33% stability, and the interosseous ligament providing 22% stability [28]. Meanwhile, the correct anatomical location of the fibula in FN relies mainly on the fixation of the anterior distal tibiofibular ligament, interosseous ligament and posterior distal tibiofibular ligaments of the DTFJ [29], and thus an increase in TFD occurs when high ankle ligaments become excessively lax after a sprain caused by contact with an external force, so that the normal position of the fibula cannot be maintained. As it can be seen in our study, this injury effect was more pronounced in shallow flat type FN.

The complex ligamentous and osseous anatomy of the syndesmosis provide stability for the ankle mortise by fixing the distal fibula to the FN [19]. Therefore, the injury of distal tibiofibular syndesmosis can lead to abnormal mechanical distribution of ankle joint and widening of ankle mortise. In our study, we explored the relationship between FN morphology and ankle mortise indexes for the first time. Previous studies demonstrated a 42% reduction in contact area of tibiotalar joint when the ankle mortise was widened by one mm , whereas the absence of timely diagnosis and treatment leads to chronic ankle instability, arthrosis, and further injuries [30,31]. Our study found that the FTiW, MTiW, PTiW and DOAM of HAS patients with shallow flat FN in males were significantly greater than those in normal people ($P<0.05$) (Table1). Among the males with deep concave type, only DOAM had statistical differences, and the HAS group was greater than the control group. Similarly, female HAS patients with shallow flat FN had significantly greater FTiW and MTiW than the normal population ($P<0.05$) (Table2). In the female with deep concave type of FN, there was no significant difference between the HAS group and the normal group in the ankle mortise indexes measured. From our results, ankle mortise indexes do not seem to be a good evaluation of the presence or severity of HAS compared with TFD, which may be related to our small sample size. But it is clear that patients with shallow flat FN tend to have more abnormal increase in ankle mortise indexes than patients with deep concave FN. Once the distal tibiofibular syndesmosis is injured or separated, the ankle mortise will be widened to varying degrees, resulting in the increase of the mobility of the talus in ankle mortise, the instability of the ankle joint and the loss of the function of the fibula to limit the outward movement of the talus [32]. Later, the outward movement of talus during weight-bearing walking will reduce the contact area of tibiotalar joint, increase the local stress and change the distribution of joint surface, which is likely to cause ankle mortise instability and traumatic arthritis [32]. So, HAS patients with shallower FN can have a worse prognosis [32].

There are several limitations in our study. (1) We chose to measure FN related parameters at ten mm above tibial plafond, which is consistent with previous studies and easy to compare similar studies, but there were studies that suggested the best measurement site was five mm above[16,33]. Therefore, certain parameters at different levels could be added in the later study [11]. (2) The force across the ankle joint can reach almost four times that of the body weight in normal ambulation, and studies have found that patients with deep concave FN have significantly higher Body Mass Index (BMI) [12,34]. So, body weight can have an impact on the depth of FN, but this is a factor that was not considered in our research. (3) Although the most common morphologic classifications of the FN are deep concave type or shallow flat type, there are the following descriptions in other studies: crescent, trapezoid, chevron and widow’s peak [35]. In the following research, we will increase the number of research samples to classify FN more carefully.

Conclusion

In our study, we excluded the morphological differences caused by gender itself at first, and then divided all patients and normal subjects by FN depth, and compared TFD and ankle mortise indexes. The results showed that the TFD of HAS patients increased significantly compared with normal people, and there were significant differences in some ankle mortise indexes, but more importantly, the above abnormalities were often more common in HAS patients with shallow flat type. Such results suggest that shallower FN may be related to more serious injury of distal tibiofibular ligament and widening of ankle mortise, resulting in a worse prognosis.

Abbreviations

HAS: High ankle sprain; DTFJ: Distal tibiofibular joint; FN: Fibular notch; TFD: Tibiofibular distance; aTFD: Anterior tibiofibular distance; mTFD: Middle tibiofibular distance; pTFD: Posterior tibiofibular distance; DOAM: Depth of ankle mortise; TiW: Tibial width; FTiW: Front tibial width; MTiW: Middle tibial width; PTiW: Posterior tibial width; SD: Standard deviation; BMI: Body Mass Index.

Declarations

Ethics approval and consent to participate

Since our study is a retrospective study, we only need to obtain the patient's informed verbal consent without informed written consent, and we can access the patient's relevant data with the consent of the

Ethical Committee of The Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University. The ethics committee that approved our study did not waiver informed consent, but rather we only required verbal informed consent from the patient. Approval was granted by the Ethical Committee of The Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University (No. KY2018043). All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

All study participants provided verbal consent to take part in the study and all authors agree to publication. This manuscript has not been published in any journals.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request, and we are willing to share the research data after the article is published.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Xiaoyao Peng: conception and design, edit, and process articles; Fan Su: conception, design and instruction; Xiangyu Tang: edit and process articles; Yuening Yang: picture data processing and statistical analysis; Junyao Chen: edit and process articles; Guixuan You: picture data processing and statistical analysis; Lei Huang: data collection and literature search; Guoyou Wang and Lei Zhang: data collection and literature search. All authors read and approved the final manuscript.

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Figures

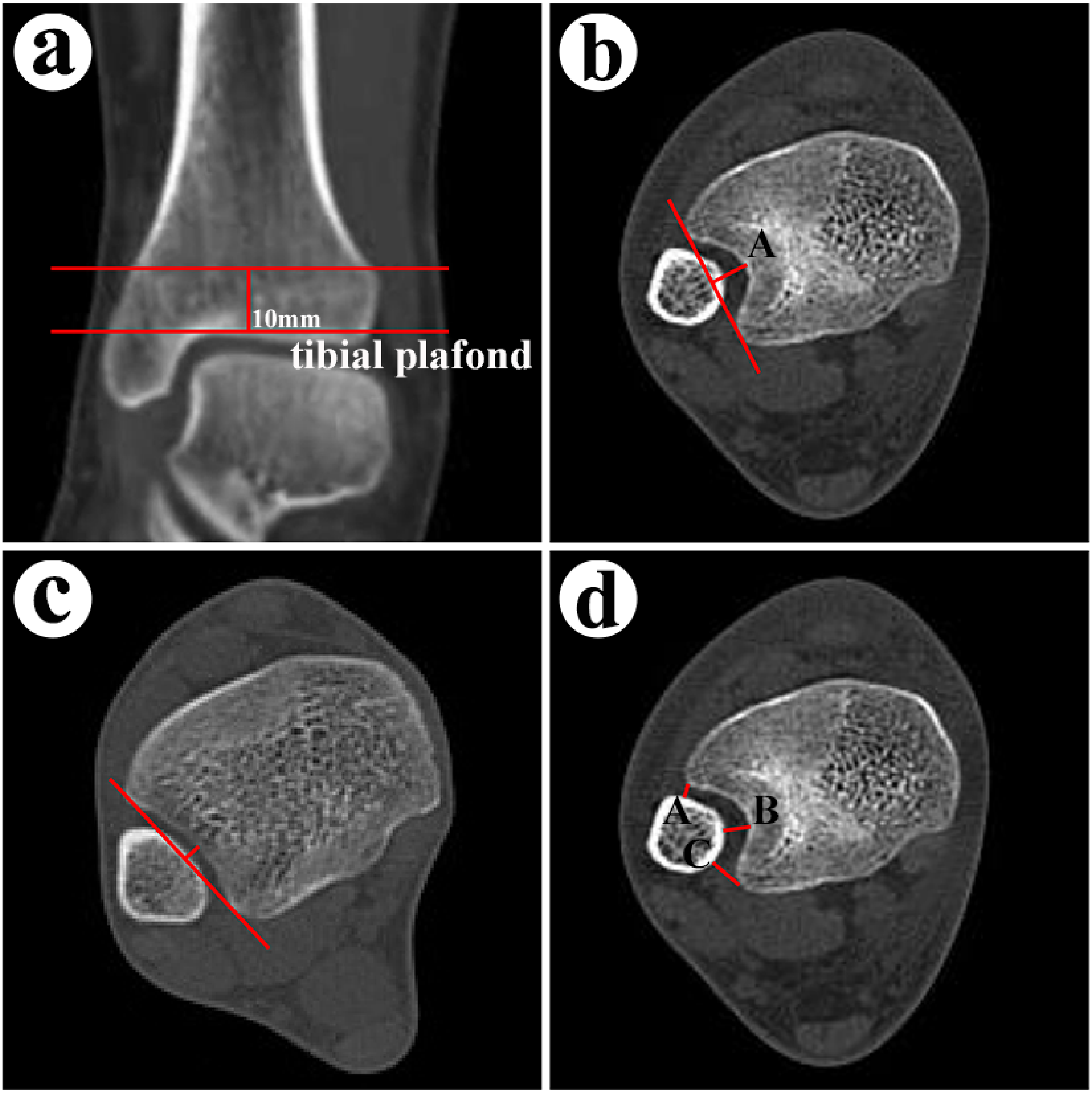

Figure 1

Measurement of FN related morphological parameters

(a)Axial CT section proximal to the 10mm above the tibial plafond.

(b) The deep concave type of FN. A, the deepest point at the FN; FN Depth: Distance from the point A to the nearest point on the tangent between the tip of the anterior tibial tubercle and the tip of the posterior tibial tubercle.

(c) The shallow flat type of FN.

(d)tibiofibular distance(TFD)：

Anterior tibiofibular distance (aTFD): A, the anterior border of the fibula; the distance between the point A and the nearest perpendicular point from point A on anterior tibial tubercle.

Middle tibiofibular distance (mTFD): B, the deepest point at the incisura, the distance between the point B and the nearest point from point B on the fibula.

Posterior tibiofibular distance (pTFD): C, the medial border of the fibula; the distance between the point C and the nearest perpendicular point from point C on the lateral border of the posterior tibial tubercle.

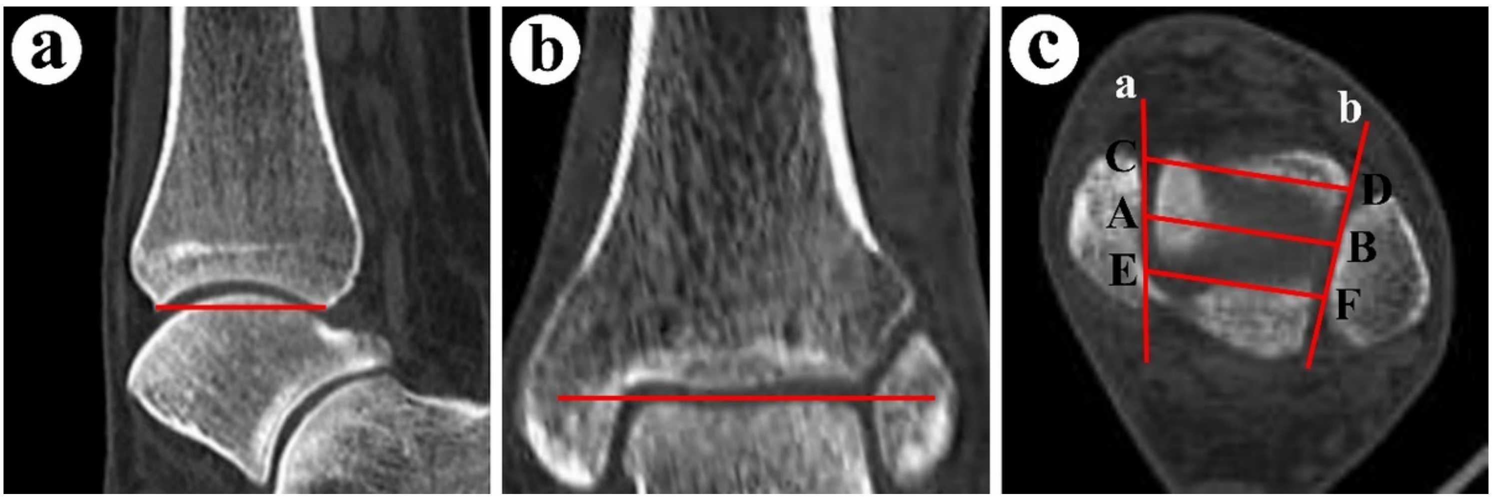

Figure 2

Measurement of Ankle Mortise Indexes

(a)Depth of ankle mortise(DOAM)：The distance between the anterior and posterior malleolus in the sagittal plane.

tibial width (TiW):

(b)Axial CT section proximal to the tangential plane to both dome of the talus.

(c)A, the middle points of the medial malleoli; B, the middle points of the lateral malleoli;

Front tibial width (FTiW): Draw a tangent line (a) of medial malleolus through point A and a tangent line (b) of lateral malleolus through point B; Draw a tangent of tibia parallel to AB and intersect with tangents a and b at two points C and D, and CD is FTiW.

Middle tibial width (MTiW): between point A and point B.

Posterior tibial width (PTiW): Draw a tangent line of the posterior ankle parallel to AB, intersect with tangent lines a and b at two points E and F, and EF is the PTiW.