

Analysis of Normal Ankle Radiographic Angles

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Abstract

Background

Understanding the position of the normal ankle is the key before every successfully surgical planning. The aims of our study were to quantify the normal ankle angles, measures and reference points systematically on ankle radiographs.

Methods

A total of 900 angles and 300 basic information were measured on 100 healthy ankles. The radiographic measurements were performed on standard weight-bearing anteroposterior (AP) and lateral view of the ankle. A total of 6 angles were made from the AP view, 3 angles from the lateral view. All angles were measured by 2 foot and ankle surgeons, independent of each other. For intraobserver reliability, after six weeks, the same angles were measured by each observer.

Results

A total of 900 angles and 300 basic information were measured on 100 healthy ankles. The mean age of the subjects was 33.0 ± 9.1 years, with 57 females(57%) and 43 males(43%), with 44 left feet(44%) and 56 right feet(56%). Intraobserver is reliability greater than 0.8 and the interobserver reliability greater than 0.8. The following angles were measured from the AP of ankle: TAS's angle, TT's angle, TC's angle, TMM's angle, TLM's angle, MA's angle. The following angles were measured from the lateral view: TLS's angle, Kite angle, TTA's angle.

Conclusions

Our study will provide a set of standard angle measures. The range of angles can be used as a reference for preoperative design and intraoperative and postoperative evaluations.

Backgrounds

The ankle supports the weight of the body, and when a fracture occurs, the most significant aspect of restoration of the anatomical alignment during treatment[1]. It is universally accepted that poor ankle articular reduction will accelerate development of post traumatic ankle osteoarthritis[2, 3]. Proper ankle osteoarthritis correction requires extensive surgical experience and radiographic information[4]. Ankle osteoarthritis are evaluated in an objective manner with radiographic evaluation. Radiographs of the ankle provide information regarding the integrity of the ankle joint. Critical preoperative planning and intraoperative evaluation of radiographs are very significant for successful ankle osteoarthritis correction.

Several studies have reported normal foot and ankle radiographic measurements, with various limitations[5-12]. Fusion and Smith[5] studied the angular relationships of the foot on lateral radiographs. They reported a total of eighty-four radiographs of the foot. Steel et al[6] studied the wide variation about radiographic measurements of the normal adult foot. Their report demonstrated the bony relationships of the normal adult painless foot. Charles et al[7] reported the reliability of fifty standard feet radiographic measurements. They studied the inconsistency of interobserver about the measurements. Thomas et al[8] reported radiographic angles of one hundred adult feet. They used a novel measuring techniques. Oscar Castro-Aragon et al[9] reported the differences of the three different ethnic feet radiographic measurements. They demonstrated that there are morphological differences among different ethnic groups. However, their studies were only included the measures of the foot. Their studies did not comment on any type of the ankle.

Alexej Barg et al[10] analyzed the influence of ankle position and radiographic projection angle on measurement of supramalleolar alignment on the two views. They found the difference of the measurements of the medial distal tibial angle(MDTA) with the hindfoot alignment views(HAV) and AP. They only reported the MDTA. Others angle of the ankle was not investigated in their study. Also, the study was included only seven samples. And their study was limited because all samples were male cadaveric.

Bradley et al[4] reported the radiographic angles, measurements and reference points of twenty-four normal feet and ankles. They presented a comprehensive and useful set of standard angles and reference points. Although their study has thirty-three angles and reference points, the data from twenty-four healthy feet were included. And this study only has five angles of ankle.

Changjun Guo et al[11] studied the reliability of measurements of fifty lateral ankle radiographs. They discovered that surgeon could find an incongruous ankle joint on lateral radiographs when the displacement of the joint circle center of talus and the distal tibia articular was 4mm. They only analyzed the data from lateral radiographs and performed three measurements.

Michael et al[12] reported eighteen observers can achieve different results on standard foot and ankle radiographic measurements. Their research not only solidified the knowledge of the normal foot and ankle radiographic angles, but also provided some insight into variability of different observers. However, their study has its limitations. The primary author is taking part in the angle analysis team. And they only analyzed 4 angles of ankle.

There are several literature of foot radiographic measurements, however, lacking of the study that comprehensive analysis of standard ankle radiographic angles. The aims of our study were to quantify the normal ankle angles, measures and reference points systematically on ankle radiographs. Our study will provide a set of standard angle measures. The data can be used as a reference for preoperative design and intraoperative and postoperative evaluations.

Materials And Methods

A total of 9 angles and 3 characteristics were measured using 100 normal feet and collected from June 2018 to November 2019. The radiographic measurements were performed on standard weight bearing anteroposterior (AP) and lateral view of the ankle. A total of 6 measurements were made on the AP view and 3 measurements were made from the lateral view (Tables 1 and 2) (Figs. 1,2 and 3). All radiographic angles were measured by 2 foot and ankle surgeons, independent of each other. For intraobserver reliability, after six weeks, the same angles were measured by each observer.

Table 1: Radiographic angle definitions: anteroposterior (AP) view

Radiographic angle	Definition
TAS (tibial anterior surface angle)	Angle formed between the anatomic axis of the tibia and the joint orientation line of the distal tibia
TT (talar tilt angle)	Angle formed by the joint orientation line of the distal tibia and talar dome
TC (tibial-mortise angle)	Angle formed between the anatomic axis of the tibia and the transmalleolar axis
TMM (tibial medial malleolus angle)	Angle formed between the anatomic axis of the tibia and the joint orientation line of medial malleolus
TLM (tibial lateral malleolus angle)	Angle formed between the anatomic axis of the tibia and the joint orientation line of lateral malleolus
MA (medial-lateral malleolus angle)	Angle formed between the joint orientation line of medial malleolus and lateral malleolus

Table 2: Radiographic angle definitions: lateral view

Radiographic angle	Definition
TLS (tibial lateral surface angle)	Angle formed between the anatomic axis of the tibia and the joint orientation line of the distal tibia
Kite angle (talocalcaneal angle)	Angle formed between the anatomic axis of the talus and calcaneal
TTA (talus tilt angle)	Angle formed between the anatomic axis of the talus and the weightbearing surface

Table 3: Normal ankle angles, descriptive statistics (N=900 radiographs of 100 ankles)

Radiograph view	Angle	(95% CI)	Mean±SD(°)	Median(°)	Range(°)
AP	TAS (°)	87.644to88.919	88.3±3.3	88.3	79.5to95.3
	TT (°)	0.515to0.919	0.7±1.0	0.3	0.5to0.9
	TC (°)	73.643to74.771	74.2±2.8	74.3	68.7to80.7
	TMM (°)	24.674to26.741	25.6±5.2	25.8	16.4to43.2
	TLM (°)	19.518to21.610	20.6±5.4	20.4	8.6to36.2
	MA (°)	44.305to47.490	45.8±7.6	45.1	30.5to69.6
Lateral	TLS (°)	78.904to80.507	79.7±4.1	79.3	70.0to91.3
	Kite Angle (°)	32.759to34.756	33.8±5.3	33.6	18.9to47.2
	TTA (°)	23.487to25.262	24.6±4.4	24.5	12.5-34.6

Abbreviations: AP, anteroposterior; CI, confidence interval; TAS, tibial anterior surface angle; TT, talar tilt angle; TC, tibial-mortise angle; TMM, tibial medial malleolus angle; TLM, tibial lateral malleolus angle; MA, medial-lateral malleolus angle; TLS, tibial lateral surface angle; Kite angle, talocalcaneal angle; TTA, talus tilt angle.

The radiographs of participants who reported having experienced trauma, fracture, pain, history of any foot ankle surgery or any other relevant medical history were excluded. Inclusion criteria included age greater than 18 and closed epiphysis. According to the criteria, participants on whom the radiographs were included had an age range of 18 to 45 years, a 57:43 female: male ratio and a 44:56 left: right ratio. Participants are all willing to join this study. The senior professor (Z.H.M.) examined all subjects, and no gross abnormalities were noted on examination. These subjects were informed volunteers for clinical research performed under institutional review board approval.

All the data obtained were recorded using an Excel spreadsheet (Microsoft Office, 2019; Microsoft, Redmond, WA). All statistical analyses were performed using SPSS version 21.0 software (SPSS Inc., Chicago, IL). Descriptive statistics were calculated for all angles. The level of agreement between the two observers was determined by the interaction correlation coefficients (ICCs) for continuous data. The method reported by Altman [13] was used to calculate the score of reliability; a score of 0.81 to 1 mean very good, 0.61 to 0.8 mean good, and 0.41 to 0.60 mean moderate.

Radiographs

The following angles were measured from the AP of ankle: TAS's angle, TT's angle, TC's angle, TMM's angle, TLM's angle, MA's angle (Fig.2). The following angles were measured from the lateral view: TLS's angle, Kite angle, TTA's angle (Fig.3).

Measurement Technique

A detailed explanation of all angles of measurement is given in Table 1 and 2. And the measurement of every angle is shown in Fig. 2 and Fig. 3. Measurement of the ankle's angles are not simply because of the greater number of axial lines (Fig. 1). On the AP radiograph, TAS is the tibial anterior surface angle between the tibial axis and distal tibia articular surface; TT is the talar tilt angle between the distal tibia articular surface and the talar dome articular surface; TC is the tibial-mortise angle. Between the tibial axis and the distal tibiofibular which is drawn between the medial malleolus and lateral malleolus margins. TMM is the tibial axis-medial malleolus angle between the tibial axis and the medial malleolus articular surface. TLM is the tibial axis-lateral malleolus angle between the tibial axis and the lateral malleolus articular surface. MA is the medial malleolus and lateral malleolus angle between the medial malleolus articular surface and lateral malleolus articular surface. On the Lateral radiograph, TLS is the lateral tibial surface angle between the tibial axis and distal tibia articular surface which is drawn between the anterior margin and posterior margin of the tibial plafond. Kite angle is an angle between the talus axis which is drawn between the midpoint of the articular surface of the talus and the midline of the talus body and the calcaneal axis which is drawn between the midpoint of the articular surface of the anterior calcaneal and the line from the posterior superior calcaneal tuberosity to the lowest point of calcaneal. TTA is an angle between the talus axis and the line as the weight bearing surface. AND it is important to ensure the quality of the radiograph and the accuracy of reference points for the veracity of all measurements.

Results

A total of 900 radiographs and 300 characteristics from 100 normal feet were measured. The mean age of the subjects was 33.0 ± 9.1 (range 18 to 46) years, with 57 females (57%) and 43 males (43%), with 44 left feet (44%) and 56 right feet (56%). Interobserver reliability and intraobserver reliability, as determined by the ICC, were very high with regard to angles of ankle (Table 4). Intraobserver reliability is greater than 0.8 and the interobserver reliability greater than 0.8, which indicating perfect consistency in the evaluation of ankle radiographic angles.

Table 4: Intraobserver reliabilities of normal ankle radiographic angles for the 100 ankles (ICC)

Angles	Observer1(95%CI)	Observer2(95%CI)
TAS(°)	0.98(0.98-0.99)	0.90(0.81-0.95)
TT(°)	0.97(0.95-0.98)	0.92(0.87-0.96)
TC(°)	0.85(0.71-0.97)	0.89(0.82-0.94)
TMM(°)	0.97(0.92-0.99)	0.94(0.92-0.96)
TLM(°)	0.92(0.86-0.98)	0.92(0.88-0.95)
MA(°)	0.94(0.89-0.97)	0.94(0.91-0.96)
TLS(°)	0.80(0.67-0.91)	0.97(0.94-0.99)
Kite angle (°)	0.97(0.94-0.99)	0.95(0.91-0.97)
TTA(°)	0.91(0.84-0.96)	0.94(0.91-0.97)

CI, confidence interval; ICC, intraclass correlation; TAS, tibial anterior surface angle; TT, talar tilt angle; TC, tibial-mortise angle; TMM, tibial medial malleolus angle; TLM, tibial lateral malleolus angle; MA, medial-lateral malleolus angle; TLS, tibial lateral surface angle; Kite angle, talocalcaneal angle; TTA, talus tilt angle.

Discussion

Published data exist regarding any of the normal foot radiographic angles. Although these studies are commonly used and cited in orthopedics, they describe few normal ankle radiographic angles. Also, although some studies have described the normal radiographic angles of ankle, a paucity of study has been published that conveys the normal radiographic angles for the ankle as thorough and comprehensive as the data in the present study[5– 12].

The foundation of radiographic ankle angles is that the relative radiographic definitions. A bone's anatomic axis is the mid-diaphyseal line. And the joint orientation angle is the angle by between the joint line and a bone's anatomic axis or the opposite joint line[4, 14].

The present study does have its limitations that should be mentioned. First, our data were only measured by two panelists. Ideally, measurements should have more team members to do. A second limitation is that this study was limited to a set of the AP and lateral X-ray of the ankle. Because we want to minimize the potential risk to the volunteers. Therefore, this study not only collected the large data but also had a lot of participants. We believe that these angles and reference points not previously reported, which can be valuable in clinical practice.

The TAS angle is very significant for the preoperative planning of ankle osteoarthritis. TAS is an angle formed between the anatomic axis of the tibia and the joint orientation line of the distal tibia. In varus ankle osteoarthritis(OA), the varus of tibial plafond is increasing as the stage of OA deteriorates[15]. The TAS angle can indicate the degree of the tibial varus. Nevertheless, we found it is different of the TAS angle compared with the previous study. The TAS angle has been measured as 92.4 ± 3.1 degrees (range ,88.0 -100.0 degrees) by Hinterman et al [16]. But the TAS angle has been measured at 88.3 ± 3.3 degrees (range,87.6–88.9 degrees) in our study. Hinterman et al[16] collected a cohort of 93 asymptomatic control subjects. And our study has 100 normal ankles were measured. Therefore, the sample could not have played role in the difference in the TAS angle. As far as we know, our study is the first measurement of the TAS angle about China. Maybe there are differences in the angles of ankle among different race.

The TLS angle is formed between the anatomic axis of the tibia and the joint orientation line of the distal tibia which is drawn between the anterior and posterior margins. The TLS angle can illustrate the position of the tibial plafond on lateral X-ray. Changjun Guo et al[11] reported the measurement of the TLS angle. In their study, three observers measured the TLS angle. The TLS angle has been measured firstly as 81.9 ± 1.92 degrees, 78.3 ± 3.64 degrees and 79.1 ± 3.67 degrees, respectively. In our study, the TLS angle has been measured as 79.7 ± 4.07 degrees. The data of the TLS angle are very close. Maybe there are similar in the angles of ankle among one ethnic. However, these need a large of a sample to prove.

The present study also researched the other angles to measure the data and reference points. Overall, this study finishes a systematic comprehensive measurement system of the normal ankle. These data will be valuable for surgeons and clinicians in the assessment of the ankle.

In conclusion, the data collected in this study have presented a comprehensive and valuable set of standard radiographic angles and reference points. These data will be useful in preoperative planning and intraoperative adjustment and postoperative evaluations of the ankle. A total of 9 angles of ankle was measured in our study, which can illustrate the ranges of the ankle position in the normal Chinese.

Abbreviations

AP, anteroposterior;

CI, confidence interval;

TAS, tibial anterior surface angle;

TT, talar tilt angle;

TC, tibial-mortise angle;

TMM, tibial medial malleolus angle;

TLM, tibial lateral malleolus angle;

MA, medial-lateral malleolus angle;

TLS, tibial lateral surface angle;

Kite angle, talocalcaneal angle;

TTA, talus tilt angle.

Declarations

Ethics approval and consent to participate

Consent for publication

Availability of data and materials

The data of this study are real. The statistical results of these data are presented in this paper. All of the data will be available upon reasonable request of the corresponding author.

Competing interests

The authors declare no competing interests.

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None.

Authors' contributions

ZWX and DJH designed the study, analysed the data, and wrote the manuscript. LY, LJQ and ZY collected the data and helped write the manuscript. ZHM and LXJ analysed the data. All authors read and approved the final manuscript.

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Figures

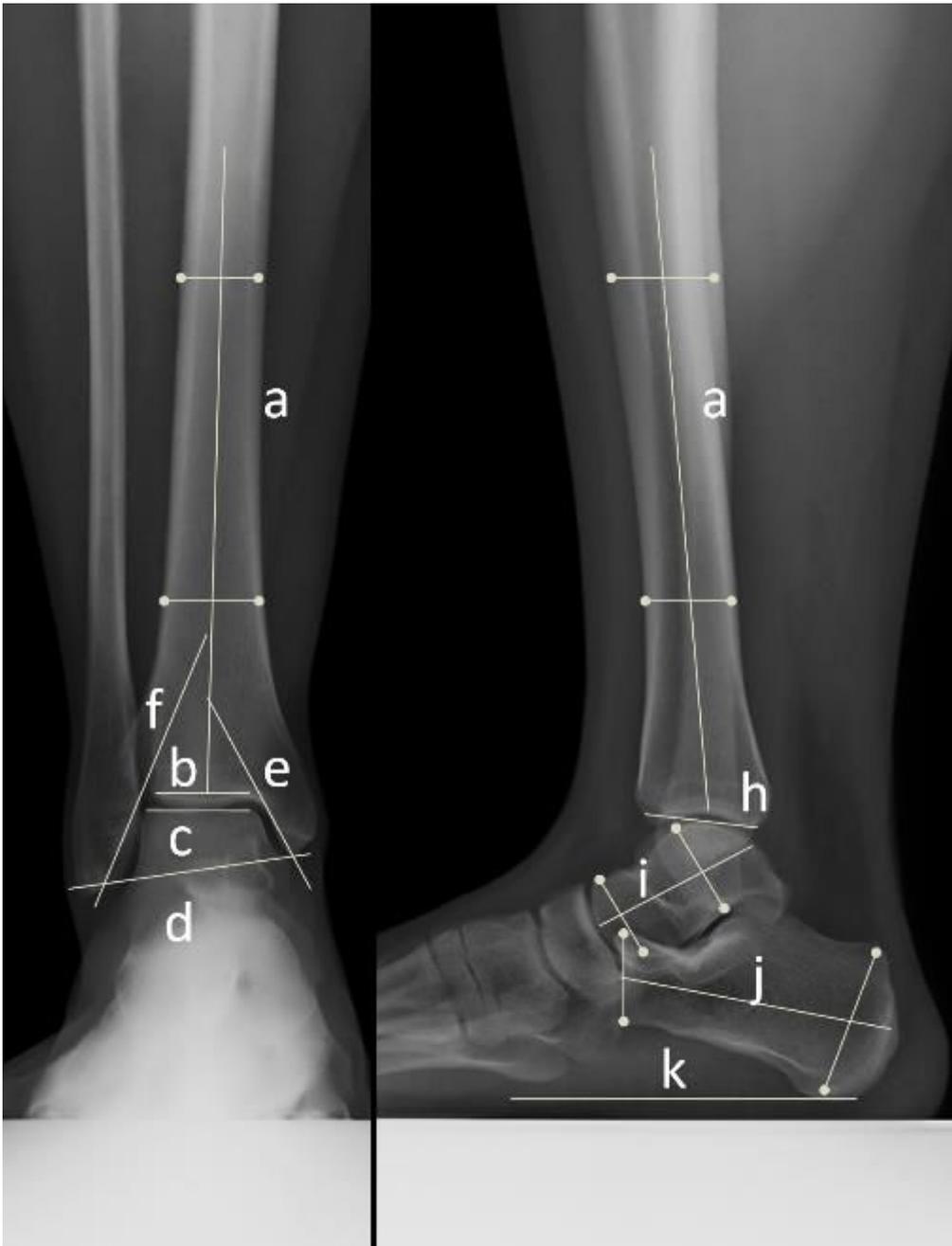


Figure 1

Anteroposterior (AP) and lateral radiograph of weight-bearing normal ankle joint. a, the anatomic axis of the tibia; b, the joint orientation line of the distal tibia; c, the joint orientation line of the talar dome; d, transmalleolar axis; e, the joint orientation line of medial malleolus; f, the joint orientation line of lateral malleolus; j: the anatomic axis of the calcaneal; h: the joint orientation line of the distal tibia; i, the anatomic axis of the talus; k, the weightbearing surface.



Figure 2

Anteroposterior (AP) radiograph measurements of weight-bearing normal ankle joint. angle 1, TAS(tibial anterior surface angle); angle 2, TMM (tibial medial malleolus angle); angle 3, TLM (tibial lateral malleolus angle); angle 4, TC (tibial-mortise angle); angle 5, MA (medial-lateral malleolus angle); angle 6, TT (talar tilt angle).



Figure 3

Lateral radiograph measurements of weight-bearing normal ankle joint. angle 1, TLS (tibial lateral surface angle); angle 2, Kite angle(talocalcaneal angle); angle 3, TTA(talus tilt angle).