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Research Article

Ankle Bone Anatomy in Turkish Population: A Radiological Study

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Abstract

Aim: While numerous geographic locations have been examined in the literature regarding the morphological characteristics of ankle bones, no studies have been conducted specifically in Turkey. Our study aims to assess the morphological features of ankle bones in individuals residing in Turkey, utilizing ankle computed tomography (CT) images obtained from patients.

Material and Methods: In our single-centre study, the data between 2018 and 2022 were scanned. The criteria for inclusion in the study were determined as being a citizen of the Republic of Turkey, being over the age of 18, and being under the age of 65.

Results: 200 patients (100 men, 100 women) and 200 ankle CT images were selected by stratified sampling using the computer-assisted randomisation method. APA, APG, MalW, MDA, MDV, MTiTh, SRTa, SRTi, TaAL, TaW, TiAL, Th, and TiW values were measured on computed tomography images.

Conclusions: The morphological structure of the ankle bone varies from society to society and according to gender. These factors should be considered in implant design (especially in prosthetic design) and the application of these implants. Our study will guide the design of ankle implants (especially prostheses) for communities living in Turkey.

Keywords: Ankle; morphology; total ankle prosthesis; ankle morphometry

INTRODUCTION

A comprehensive understanding of the ankle's anatomy and biomechanical structure is crucial when performing surgical interventions on the ankle (1-3). This information is golden, especially in cases where appropriate restoration of the ankle joint line is required (4). Some include surgery for intra-articular extension ankle fractures after high-energy trauma, total ankle arthroplasty, or ankle deformity surgery.

It is important to provide anatomical and biomechanical correlation, especially in ankle arthroplasty. In such surgeries, the correct design and application of the implant are based on knowing the normal anatomy of the ankle (5,6). While there are many geographic locations in the literature regarding the morphological features of the ankle bones, there are no studies conducted in Türkiye.

Our study aims to determine the ankle bone morphological features of individuals living in Türkiye through the ankle computed tomography (CT) images of the patients.

MATERIAL AND METHOD

The ethics committee of Dicle University approved our study (1642). Since it was a retrospective study, informed consent was not obtained. In our single-centre study, the data between 2018 and 2022 were scanned. The criteria for inclusion in the study were determined as being a citizen of the Republic of Türkiye, being over the age of 18, and being under the age of 65. Exclusion criteria were CT images that did not include all 3 sequences and were of poor quality, previous foot or ankle surgery, previous osteomyelitis, tumour, congenital deformity, or presence of conditions that may disrupt normal foot-ankle anatomy, Kellgren and Lawrence score (7) of >3 were excluded from the analysis. Two orthopaedic specialists made measurements.

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Measurement Parameters

The measurements were obtained from the computed tomography images through the radiology information management system program. The origin of the coordinate system was taken to be at the geometric centre of the talus. The anteroposterior (A/P) axis was the line joining the Achilles tendon's calcaneal insertion and the second metatarsal head, parallel to the baseplate. The mediolateral (M/L) axis was then defined as the line perpendicular to the A/P and S/I axes. The anteroposterior inclination angle of the tibial mortise (APA), anteroposterior gap (APG), malleolar width (MalW), the distance of level of MTiTh from the anterior limit of the mortise (MDA), the distance of level of MTiTh from the vertex of the mortise (MDV), maximal tibial thickness(MTiTh), the sagittal radius of the trochlea tali arc (SRTa), the sagittal radius of the tibial mortise (SRTi), trochlea tali length (TaAL), talar width (TaW), tibial arc length (TiAL)), talar tenon height (Th) and tibial width (TiW) were measured. The parameters were measured as previously described in the literature (8). The measurements of the parameters are shown in Figure 1.

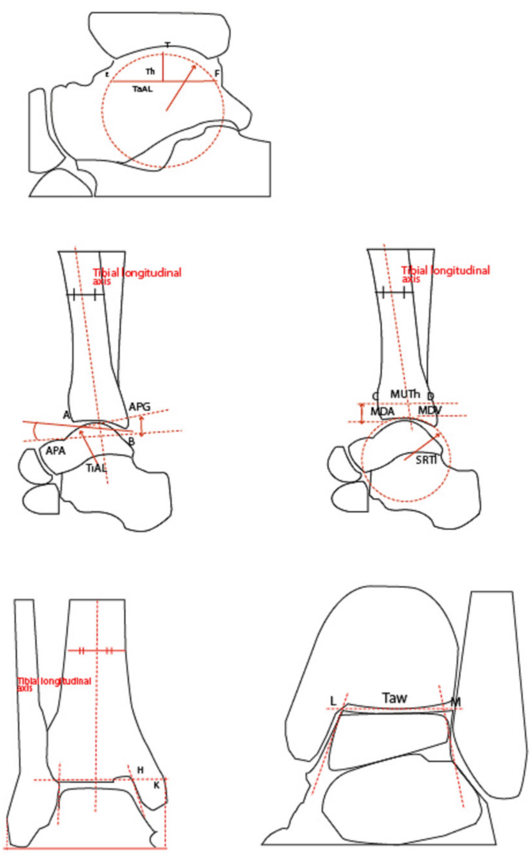

Figure 1. Morphologic measurements

To establish interobserver and intraobserver reliability, some assessments have been made. All measurements were made two times, with an interval of 2 weeks, by the clinician who made the measurement. In addition, all measurements were made again by an independent orthopaedic specialist to evaluate interobserver reliability. The intra-class coefficient (ICC) assessed interobserver and intraobserver reliability. The ICC is a value between 0 and 1, where values below 0.5 indicate poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability (9).

Statistical analyses were performed using the Statistical Package of the Social Sciences (IBM SPSS 28.0.1.0; Corp., Armonk, NY, USA). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented using means and standard deviations for normally distributed variables. The Student's T-test and one-way Student's T-test were used to compare the parameters. A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS

Between 2018-2023, 342 ankle CT images were obtained. Among the 297 ankle CT images that met the criteria, 200 patients (100 men, 100 women) and 200 ankle CT images were selected by stratified sampling using the computer-assisted randomisation method (www.randomizer.org). The mean age of the patients was 44.05±11.77. One hundred twenty-one images belong to the right ankle, and 79 belong to the left ankle. One hundred patients were male, and 100 patients were female. The mean values of APA, APG, MalW, MDA, MDV, MTiTh, SRTa, SRTi, TaAL, TaW, TiAL, Th, and TiW by gender are given in Table 1. There were significant differences between genders in all parameters except APA, APG, MDA, and MDV. In Tables 2 and 3, measurement values and comparisons made according to populations are given. Interobserver reliability was 0.91, and intra-observer reliability was 0.93.

Table 1. Mean values of ankle bone morphological parameters by gender

Gender	Male (n=100)		Female (n=100)		Total (n=200)		
	Mean	SD	Mean	SD	Mean	SD	P Value
APA(deg)	8.04	3.36	7.74	3.65	7.90	3.51	.536
APG(mm)	4.11	1.46	4.31	1.65	4.21	1.56	.374
MalW(mm)	70.39	3.18	69.41	3.49	69.91	3.37	**.039**
MDA(mm)	12.69	2.33	12.29	2.71	12.49	2.53	.264
MDV(mm)	8.23	3.50	8.14	3.65	8.19	3.57	.841
MTiTh(mm)	42.51	3.49	41.39	3.72	41.95	3.64	**.029**
SRTa(mm)	23.39	2.48	22.56	2.62	22.98	2.58	**.022**
SRTi(mm)	27.27	3.20	26.21	3.38	26.74	3.33	**.024**
TaAL(mm)	40.51	2.87	39.54	3.26	40.03	3.11	**.026**
TaW(mm)	30.44	3.30	29.53	2.81	29.99	3.10	**.036**
TiAL(mm)	30.71	3.10	29.77	3.11	30.24	3.14	**.032**
Th(mm)	11.76	1.65	11.34	1.32	11.56	1.51	**.047**
TiW(mm)	32.89	3.35	31.88	3.32	32.39	3.37	**.032**

Table 2. Comparison of ankle bone morphological parameters according to different regions

	French (10)	American (11)	Italian (12)	Korean (8)	Taiwan (13)	Northeast China (13)	Türkiye
APA(deg)	8.3±1.4	-	5±3.4	8.2±3.2	7.4±5.7	9.1±2.1	7.90±3.51
APG(mm)	-	-	2.7±1.8	4.2±1.7	3.6±2.8	4.8±1.0	4.21±1.56
MalW(mm)	-	-	69	67.6	63.1±3.4	66.6±3.9	69.91±3.37
MDA(mm)	-	-	11.5±3.5	12.4±2.7	11.4±4.0	9.3±1.3	12.49±2.53
MDV(mm)	-	-	8.7±3.5	10±10	4.0±2.2	6.2±1.3	8.19±3.57
MTiTh(mm)	-	-	41.4±3.9	39.4±3.6	42.0±5.1	40.8±2.6	41.95±3.64
SRTa(mm)	-	20.7±2.6	23.4±3.1	21.5±2.6	-	-	22.98±2.58
SRTi(mm)	-	-	27.8±4.4	23.3±2.8	-	-	26.74±3.33
TaAL(mm)	38.5±2.2	-	41.7±4.4	35.3±3.6	32.3±4.1	33.4±2.8	40.03±3.11
TaW(mm)	31.4±2.5	27.9±3	30.4±3.3	30.5±3	20.9±3.0	28.5±2.1	29.99±3.10
TiAL(mm)	30.8±3.0	-	31.4±3.5	29.2±2.9	28.4±2.9	29.4±1.6	30.24±3.14
Th(mm)	12.1±1.5	-	-	10.5±1.1	11.9±1.8	10.6±1.4	11.56±1.51
TiW(mm)	34.5±2.3	-	31.9±3.5	31.3±3.1	33.3 ± 2.5	33.4±2.2	32.39±3.37

Table 3. Comparison of Türkiye's and different regions' data with one-way Student T-test

	French (10)	American (11)	Italian (12)	Korean (8)	Taiwan (13)	Northeast China (13)
APA(deg)	0.104	-	**<0.001**	0.221	0.047	**<0.001**
APG(mm)	-	-	**<0.001**	0.933	**<0.001**	**<0.001**
MalW(mm)	-	-	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MDA(mm)	-	-	**<0.001**	0.605	**<0.001**	**<0.001**
MDV(mm)	-	-	0.044	**<0.001**	**<0.001**	**<0.001**
MTiTh(mm)	-	-	**0.032**	**<0.001**	0.861	**<0.001**
SRTa(mm)	-	**<0.001**	**0.021**	**<0.001**	-	-
SRTi(mm)	-	-	**<0.001**	**<0.001**	-	-
TaAL(mm)	**<0.001**	-	**<0.001**	**<0.001**	**<0.001**	**<0.001**
TaW(mm)	**<0.001**	**<0.001**	0.063	**0.021**	**<0.001**	**<0.001**
TiAL(mm)	0.463	-	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Th(mm)	**<0.001**	-	-	**<0.001**	**<0.001**	**<0.001**
TiW(mm)	**<0.001**	-	**0.042**	**<0.001**	**<0.001**	**<0.001**

Data in the table are p values, the significance level was set at 0.05

DISCUSSION

The morphological structure of the ankle may vary from society to society. Knowing these changes is essential in choosing individual or community-specific implants (especially ankle arthroplasty) in ankle surgery. Our study found that the ankle morphometric structure of Turkish society differed from the other societies described in the literature.

In radiological studies to determine the morphometric features of any anatomical structure, the X-ray is an advantageous method to give cheap, simple, and fast results. However, besides this advantage, there are also some disadvantages. Cross-sectional image limitations, contrast limitations, the image overlap are a few of them (14). In addition, the angle of the tube during shooting and the lack of shooting at the appropriate dose also affect the image quality. On the other hand, computed tomography (CT) provides a higher resolution, thin section, and 3D image when necessary. In similar studies in the literature, measurements were made with the help of direct radiography or computerised tomography (8,9,12,13). In the study of Hongyu et al., CT images gave more accurate results than X-ray images (13). Stagni et al. reported that there were differences in CT and X-ray measurements, but they were not significant in most parameters, and this was due to the small number of samples (15). For the reasons mentioned above, it was deemed appropriate to make measurements on computed tomography in our study. To minimise the margin of error, measurements were made 2 times on different dates by 2 different clinicians. Interobserver and intra-observer reliability were found to be excellent.

When we look at the morphological measurements of the ankle, we see that the measurements differ from society to society in studies conducted in France, Italy, Korea, Taiwan and Northeast China (13). These differences can help the surgeon to make a more accurate decision in ankle surgery operations. Although there is no geographical distinction in orthopaedics in the design, production and development phase of implants, differences can be important, especially in ankle prostheses, according to the geographical region. To prevent the negative effects of these anatomical variations on surgery, custom-made implant production has become widespread. However, it is used in selected cases because personalised production is costly and time-consuming. Hongyu et al. concluded that total ankle prostheses designed for Caucasians are unsuitable for the northeast Chinese population (13). In our study, it was found that APA, APG, MalW, MDA, MDV, MTiTh, SRTa, SRTi, TaAL, TaW, TiAL, Th, and TiW values differ in the Turkish population compared to other populations (Table 2, 3).

These parameters, measured in our study and differed in Turkish society, have various clinical significance. Ensuring optimal physiological and biomechanical harmony is important in orthopaedic surgery, especially in joint and prosthetic surgery. A larger APA in total ankle replacement surgery indicates that the distal tibial segment should be larger. Because this bone cut is made at an angle of 90 degrees to the anterior of the distal tibia. Also, the possibility of fractures in the medial and lateral malleolus is higher (16). In the study of Stagni et al. (15) stated that knowing the MDV, MDA, APG, and APA values is essential in determining the optimal level and inclination of the bone cut. In addition, these data are precious in the design of the prosthesis and instrumentation used in the operation because the preservation of the bone stock as much as possible depends on the appropriate design of the prosthesis.

The present study determined statistically significant differences in the parameters related to the size of the male and female groups. It is concluded that gender can also significantly affect the design of orthopaedic implants. In our study, it was determined that the ankle sizes of men were larger than women. It is a detail that needs attention in implant design, ankle surgery and especially in total ankle arthroplasty.

There are certain limitations of our study. Evaluating the ankle joint with bone tissue alone will not give accurate results. There are many factors affecting ankle instability (17). It is necessary to consider them as a whole. In addition, lower extremity alignment, muscle strength and other soft tissue factors are also crucial for the normal function of the ankle. In this respect, biomechanical studies are needed to test the reflection of the differences in the anatomical structure of the ankle on the clinical picture. Although our hypothesis claims these differences are clinically important in implant selection and prosthesis design, studies are needed to compare long-term functional, radiological and surgical outcomes in large patient groups. Another limitation of our study is that it is retrospective.

CONCLUSION

As a result, the morphological structure of the ankle bone varies from society to society and according to gender. These factors should be considered in implant design (especially in prosthetic design) and the application of these implants. Our study will guide the design of ankle implants for communities living in Türkiye. These data will be guiding especially for ankle prostheses to be produced in Türkiye.

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Conflict of Interest: *The authors have no conflicts of interest to declare.*

Ethical approval: *The ethics committee of Dicle University approved our study (1642,14.03.2022).*

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