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Research

The Morphometrical Characteristics of the Proximal Tibia in the Anatolian Population

Anadolu Toplumunda Tibia Proksimalinin Morfometrik Özellikleri

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ABSTRACT

Objective: Our study aimed to analyze the proximal tibia measurements of the Anatolian population to improve the design of appropriate prostheses in knee arthroplasties.

Methods: Specific morphometric measurements, including anteroposterior and mediolateral measurements of the condyles, tibial plateau, and proximal tibial circumference, were performed on 68 dry human tibias from the Anatolian population using digital calipers, and compared by statistical methods.

Results: Our study revealed significant differences between the proximal tibia morphometric measurements of the Anatolian population and other populations. Mean proximal tibia circumference, tibial plateau, and tibial tuberosity distances were significantly higher compared to the control group.

Conclusion: Population-specific data are important for optimizing tibial prosthesis design. Personalized treatments based on tibial morphometric measurements can better adapt tibial components in knee arthroplasties and improve individuals' functionality. Further studies are needed to increase the accuracy of tibial morphometric data with computed tomography support, and minimize age and sex differences.

Keywords: Tibial morphometry, arthroplasty, Anatolian population

ÖZ

Amaç: Çalışmamızın amacı, diz artroplastilerinde uygun protezlerin tasarımını geliştirmek için Anadolu popülasyonunun proksimal tibia ölçümlerini analiz etmektir.

Gereç ve Yöntem: Anadolu popülasyonuna ait 68 kuru insan tibiası dijital kumpas kullanılarak kondillerin anteroposterior ve mediolateral ölçümleri, tibial plato ve proksimal tibia çevresi dahil olmak üzere spesifik morfometrik ölçümleri yapılmış ve istatistiksel metodlarla karşılaştırılmıştır.

Bulgular: Çalışmamız, Anadolu popülasyonunun proksimal tibia morfometrik ölçümleri ile diğer popülasyonlar arasında önemli farklılıklar olduğunu ortaya koymuştur. Ortalama proksimal tibia çevresi, tibial plato ve tuberositas tibia mesafeleri anlamlı olarak daha yüksekti.

Sonuç: Popülasyona özgü veriler, tibial protez tasarımının optimizasyonu için önemlidir. Tibial morfometrik ölçümlere dayalı kişiselleştirilmiş tedaviler, diz artroplastilerinde tibial bileşenlerin daha iyi adaptasyonunu sağlayabilir ve bireylerin işlevselliğini artırabilir. Bilgisayarlı tomografi desteği ile tibial morfometrik verilerin doğruluğunun artırılarak, yaş ve cinsiyet farklılıklarının en aza indirildiği ileri çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Tibial morfometri, artroplasti, Anadolu popülasyonu

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INTRODUCTION

The knee joints are susceptible to different structural and traumatic pathologies. Deformity in the proximal tibia, which is a part of the knee joint, disrupts the stabilization of the joint and impairs the overall quality of life. In the proximal tibia, damage on the upper articular facet may cause pain and limitation during joint movement (1). Total knee arthroplasty (TKA) is a treatment method preferred for patients in later stages to improve joint functionality and relieve pain. In arthroplasty, the tibia is more predisposed to complications than the femur. To obtain an optimal response from TKA, an anthropometrically optimized knee prosthesis is required (2,3). In the literature, there are studies on the morphometry of the tibia in different populations (4,5). Recent anthropometric studies on the tibia have shown that the current tibial implants used for TKA are not entirely appropriate for all populations due to interracial differences (6-9). Appropriate dimensioning of the tibial component in TKA is essential to maximize weight distribution proximal to the tibia. If the tibial component is small, loosening of the prosthesis may occur in the early postoperative period due to inadequate tibia support. A small tibial component increases the risk associated with unicondylar knee arthroplasty. If the implant is larger than needed, the protruding part may cause pain in the patient by irritating soft tissues (10). Our study aims to increase the success of surgical procedures by determining the proximal tibia parameters in the Anatolian population. Thus, the aim is to reduce postoperative pain, unnecessary reoperations, and financial and psychological losses. An increase in the success of surgical results will improve patients' quality of life. We think the data obtained will guide procedures such as knee replacement involving the proximal tibia.

METHODS

In this study, 68 human dry tibiae from adults of unknown age and sex, from the Anatolian population, without bone pathology were analyzed. All of these bones were sourced from the dried bone collection at the Department of Anatomy, Selçuk University Faculty of Medicine. It has obtained ethical approval from the Local Ethics Committee of Selçuk University (approval no: 2023/469, date: 13.10.2023). A digital caliper (Insize 1108/Suzhou, People's Republic of China) with a measuring range of 0-150 mm and an accuracy of 0.03 mm was utilized for parameter measurements. Caliper calibration was performed before each measurement. An authorized expert conducted all measurements twice, and the average of the two measurements was calculated. The detailed measurements are illustrated in Figure 1.

This study involving human participants was conducted in accordance with the ethical standards established by the institutional and national committees, following the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Since data for this study were obtained from the dry bone collection of our faculty, there is also no informed consent form.

Statistical Analysis

The data collected from the study were evaluated using the IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA) software. A value of $p<0.05$ was considered significant. The minimum, maximum, mean, and standard deviation of the data were calculated. Normal distribution of the data was assessed using skewness and kurtosis tests. An independent samples t-test was used to compare the right and left tibia data. Data of the medial and lateral condyles were compared with the Pearson's correlation test.

RESULTS

Our study includes descriptive statistics of proximal tibia measurements of the Anatolian population. The minimum, maximum, mean, and standard deviation values of the measured bones were calculated from 68 dry bones (30 left and 38 right). When the skewness and kurtosis values of the proximal tibia measurements were analyzed, it was seen that they fit the normal distribution (Table 1). The data that will contribute to the analysis and explanation of the differences between the right and left sides of the proximal tibia are shown in Table 2.

Left-right proximal tibia measurements were compared. T-test results showed that the mean differences between the groups were not significant for "AB" ($t=-0.35$, $p=0.73$), "CD" ($t=0.78$, $p=0.44$), "EF" ($t=-1.04$, $p=0.30$), "GH" ($t=0.12$, $p=0.90$), and "IJ" ($t=0.19$, $p=0.85$), "KL" ($t=-0.19$, $p=0.85$), "MN" ($t=0.94$, $p=0.35$), "circle" ($t=0.001$, $p=0.99$), "tibial tuberosity (TT) length" ($t=-0.84$, $p=0.41$). However, there was a statistically significant difference according to the t-test results for the regions "OP" ($t=-2.85$, $p=0.01$) and "RS" ($t=-3.03$, $p=0.001$) (Table 3). The mean difference for "AB-EF" was 5.88 and the standard deviation was 3.25. The anteroposterior diameter of the medial condyle was significantly larger than the anteroposterior diameter of the lateral condyle ($t=14.93$, $p<0.001$).

The mean value of the "CD-GH" measurement difference was 1.66, and the standard deviation was 2.22. The mediolateral diameter of the medial condyle was significantly larger than the mediolateral diameter of the lateral condyle ($t=6.16$, $p<0.001$).

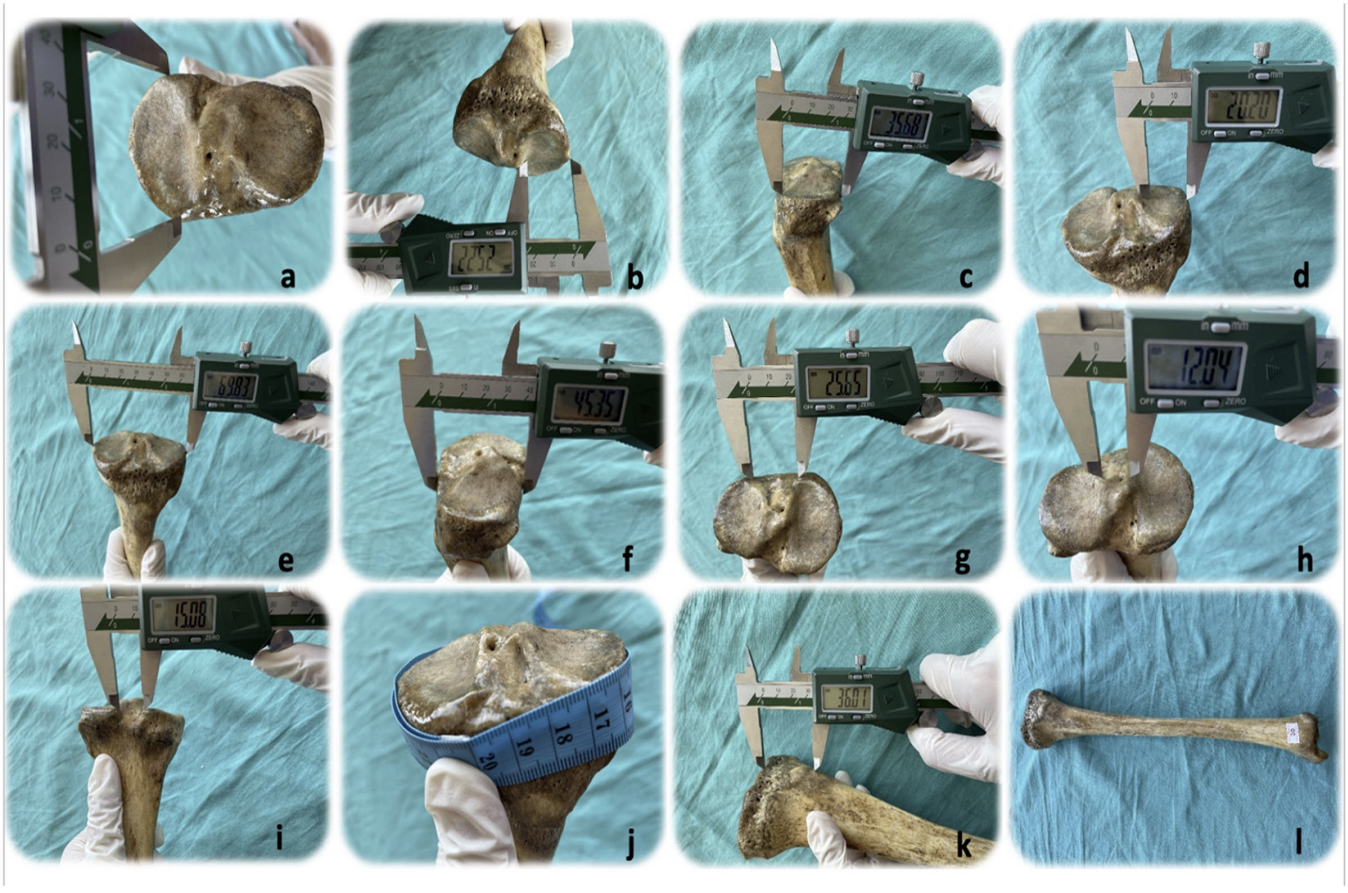

Figure 1. **(a)** Anteroposterior measurement of medial condyle (AB), **(b)** mediolateral measurement of medial condyle (CD), **(c)** anteroposterior measurement of lateral condyle (EF), **(d)** mediolateral measurement of lateral condyle (GH), **(e)** tibial plateau width measurement (IJ), **(f)** anteroposterior measurement of the intercondylar area (KL), **(g)** mediolateral measurement of the intercondylar area at the anterior end (MN), **(h)** mediolateral measurement of the intercondylar area in the middle narrow part (OP), **(i)** mediolateral measurement of the intercondylar area at the posterior end (RS), **(j)** circumference of the proximal tibia (Circle) **(k)** length between tibial plateau and tibial tuberosity (TT length) **(ı)** anterior view of the tibia

Table 1. Descriptive statistics of the proximal tibia measurement

Parameters	Min	Max	Mean	SD	Skewness	SD	Kurtosis	SD
AB	31.9	53.06	42.22	4.29	0.23	0.29	-0.10	0.57
CD	14.59	29.51	21.63	2.67	0.42	0.29	1,46	0.57
EF	28.03	46.79	36.33	3.73	0.15	0.29	0.04	0.57
GH	12.04	25.12	19.97	2.50	-0.20	0.29	0.27	0.57
IJ	52.09	78.76	67.49	5.57	-0.30	0.29	0.14	0.57
KL	37.68	58.55	46.73	4.65	0.32	0.29	-0.43	0.57
MN	18.46	36.16	25.73	3.50	0.03	0.29	0.18	0.57
OP	8.72	15.46	11.45	1.66	0.41	0.29	-0.46	0.57
RS	11.54	22.42	15.76	2.59	0.36	0.29	-0.72	0.57
Circle*	15.75	23.3	19.76	1.60	-0.05	0.29	-0.40	0.57
TT length	30.02	62.95	46.01	8.40	-0.09	0.29	-0.96	0.57

*Parameter value is cm, others are mm. AB: Anteroposterior measurement of medial condyle, CD: Mediolateral measurement of medial condyle, EF: Anteroposterior measurement of lateral condyle, GH: Mediolateral measurement of lateral condyle, IJ: Tibial plateau width measurement, KL: Anteroposterior measurement of the intercondylar area, MN: Mediolateral measurement of the intercondylar area at the anterior end, OP: Mediolateral measurement of the intercondylar area in the middle narrow part, RS: Mediolateral measurement of the intercondylar area at the posterior end, Circle: Circumference of the proximal tibia, TT length: Length between tibial plateau and tibial tuberosity, Min: Minimum, Max: Maximum, SD: Standard deviation, n: Number

Table 2. Left-right side comparison data of the proximal tibia

Parameters	Side	n	Mean	SD	SE
AB	Left	30	42.01	3.78	0.69
	Right	38	42.37	4.69	0.76
CD	Left	30	21.91	2.55	0.46
	Right	38	21.41	2.77	0.45
EF	Left	30	35.81	3.50	0.64
	Right	38	36.74	3.89	0.63
GH	Left	30	20.01	2.09	0.38
	Right	38	19.93	2.81	0.45
IJ	Left	30	67.63	4.45	0.81
	Right	38	67.38	6.37	0.03
KL	Left	30	46.12	4.01	0.73
	Right	38	47.21	5.10	0.83
MN	Left	30	26.17	3.08	0.56
	Right	38	25.38	3.81	0.62
OP	Left	30	10.84	1.50	0.27
	Right	38	11.93	1.64	0.26
RS	Left	30	14.78	1.93	0.35
	Right	38	16.53	2.81	0.45
Circle*	Left	30	19.76	1.29	0.23
	Right	38	19.76	1.83	0.30
TT length	Left	30	45.04	8.38	1.53
	Right	38	46.77	8.46	1.37

*Parameter value is cm, others are mm. AB: Anteroposterior measurement of medial condyle, CD: Mediolateral measurement of medial condyle, EF: Anteroposterior measurement of lateral condyle, GH: Mediolateral measurement of lateral condyle, IJ: Tibial plateau width measurement, KL: Anteroposterior measurement of the intercondylar area, MN: Mediolateral measurement of the intercondylar area at the anterior end, OP: Mediolateral measurement of the intercondylar area in the middle narrow part, RS: Mediolateral measurement of the intercondylar area at the posterior end, Circle: Circumference of the proximal tibia, TT length: Length between tibial plateau and tibial tuberosity, SD: Standard deviation, SE: Standard error, n: Number

Table 3. Independent sample t-test for left-right proximal tibia measurements

Parameters	t-test for equality of means						
	t	df	p-value	Mean difference	SE	95% confidence interval	
						Low	Up
AB	-0.35	65.96	0.73	-0.36	1.03	-2.41	1.69
CD	0.78	64.41	0.44	0.5	0.65	-0.79	1.8
EF	-1.04	64.84	0.30	-0.94	0.9	-2.73	0.86
GH	0.12	65.8	0.90	0.07	0.59	-1.11	1.26
IJ	0.19	65.14	0.85	0.25	1.31	-2.37	2.88
KL	-0.99	66	0.33	-1.09	1.11	-3.3	1.12
MN	0.94	65.95	0.35	0.78	0.84	-0.88	2.45
OP	-2.85	64.6	0.01	-1.09	0.38	-1.85	-0.33
RS	-3.03	64.89	0.001	-1.75	0.58	-2.9	-0.59
Circle	0.001	65.29	0.99	0	0.38	-0.76	0.76
TT length	-0.84	62.64	0.41	-1.72	2.05	-5.83	2.38

AB: Anteroposterior measurement of condylus medialis, CD: Mediolateral measurement of condylus medialis, EF: Anteroposterior measurement of condylus lateralis, GH: Mediolateral measurement of condylus lateralis, IJ: Tibial plateau width measurement, KL: Anteroposterior measurement of the area intercondylaris, MN: Mediolateral measurement of the area intercondylaris at the anterior end, OP: Mediolateral measurement of the area intercondylaris in the middle narrow part, RS: Mediolateral measurement of the area intercondylaris at the posterior end, Circle: Circumference of the proximal tibia, TT length: Length between tibial plateau and tuberositas tibia, t: t-value, df: Degrees of freedom, SE: Standart error

For the "circumference-TT length" measurement difference, the mean was -26.24 and the standard deviation was 7.63. The distance between the circle of the proximal tibia and the tibial plateau-TT was statistically significant and greater (t=-28.32, p<0.001).

DISCUSSION

There are few studies on proximal tibia measurements in the literature. Proximal tibia measurements aim to reveal differences between societies and sexes. Today, most knee implants are produced to fit the anatomical characteristics of European and North American populations. Due to anthropometric differences in the knee joint, there is an incompatibility between knee implants and the resected surfaces. This incompatibility leads to recurrence of postoperative pain, complications, and loss of quality of life (10). To resolve this incompatibility, the morphometric characteristics of different populations should be considered in tibial implant construction. Our study provides morphometric characteristics of the proximal part of the tibia in the Anatolian population.

In one of the limited number of studies in the literature (Table 4), Gandhi et al. (11) examined 100 dried human tibias from Indian populations. They measured the AB of the medial condyle as 45.23±4.34 mm and the CD of the medial condyle as 28.44±2.8 mm; the EF of the lateral condyle was 38.91±3.69 mm, and the GH of the lateral condyle was 27.4±2.95 mm. Servien et al. (12) examined the AB value of the medial condyle as 50.80±3.3 mm, the CD value of the medial condyle as 28.80±2.5 mm, the EF value of the lateral condyle as 47.20±3.3 mm and the GH value of the lateral condyle as 29.30±2.4 mm with computed tomography (CT) in 37 French patients. According to the data obtained by Zalawadia and Patel (13) from 120 human dry tibiae belonging to the Indian (Gujarat) population the AB value of the medial condyle was 42.07 mm, the CD value of the medial condyle was 27.26 mm, the EF value of the lateral condyle was 36.94 mm, and the GH value of the lateral condyle was 28.07 mm. In the study by Pradhan et al. (14), which examined 200 dry tibiae from Eastern India, AB and EF were found to be 42.72 mm and 39.44 mm, respectively. Bilkay et al.'s (15) study, conducted on 44 dry tibia bones in the Turkish population, determined that AB and EF were 41.9 mm and 36.5 mm, respectively. In the study of Toy and Secgin (16), AB, CD, EF, and GH values were found to be 47.51 mm, 30.18 mm, 43.28 mm, and 32.79 mm, respectively, in the results of 33 dry tibia bones in the Turkish population. In Shojaolsadati et al.'s (17) study, 200 proximal tibiae in the Anatolian population were examined by magnetic resonance imaging, and AB and EF were determined to be 47.1 mm and 38.5 mm, respectively. In one of the recent studies, Akdemir Aktaş et al. (4) measured the AB value of the medial condyle as 39.76±4.10 mm, the CD value of the medial condyle as 23.27±2.63 mm, the EF value of the lateral condyle as 34.72±3.51 mm, and the GH value of the lateral condyle as 21.83±2.52 mm in their study with 57 human dry tibiae from the Turkish population.

Our study's AB, CD, EF, and GH measurements were lower than those of the Indian and French populations. We think that this result may be due to ethnic differences. However, the study by Servien et al. (12) used CT data. The large size of the measurements compared to dry bone studies is a reasonable finding. Our study's values for anteroposterior diameter are consistent with the literature. In the measurements, the AB value of the

Table 4. Comparison of morphometric measurements of the proximal tibia

	AB	CD	EF	GH	IJ	KL	MN	OP	RS	Circle*	TT length
Servien et al. (12)	50.80	28.80	47.2	29.30	-	-	-	-	-	-	-
Gandhi et al. (11)	45.23	28.44	39.41	27.4	-	46.01	23.79	6,92	6,92	-	-
Bilkay et al. (15)	41.9	-	36.5	-	70.2	-	-	-	-	-	-
Zalawadia and Patel (13)	42.07	27.26	36.94	28.07	70.78	-	-	-	-	-	-
Shojaolsadati et al. (17)	47.1	-	38.5	-	77	-	-	-	-	-	-
Toy and Secgin (16)	47.51	30.18	43.28	32.79	-	-	-	-	-	-	-
Akdemir Aktaş et al. (4)	39.76	23.27	34.72	21.83	65.14	41.62	24.86	21.27	21.36	-	-
Pradhan et al. (14)	42.72	-	39.44	-	67.91	42.73	-	-	-	19.37	33.48
Our study	42.22	21.63	36.33	19.97	67.49	46.73	25.73	11.45	15.76	19.76	46.01

*Parameter value is cm, others are mm. AB: Anteroposterior measurement of medial condyle, CD: Mediolateral measurement of medial condyle, EF: Anteroposterior measurement of lateral condyle, GH: Mediolateral measurement of lateral condyle, IJ: Tibial plateau width measurement, KL: Anteroposterior measurement of the intercondylar area, MN: Mediolateral measurement of the intercondylar area at the anterior end, OP: Mediolateral measurement of the intercondylar area in the middle narrow part, RS: Mediolateral measurement of the intercondylar area at the posterior end, Circle: Circumference of the proximal tibia, TT length: Length between tibial plateau and tibial tuberosity

medial condyle was significantly higher than the EF value of the lateral condyle. Similarly, the mediolateral diameter (CD) of the medial condyle was significantly greater than the mediolateral diameter (GH) of the lateral condyle ($p<0.05$). These results are a possible consequence of the asymmetry of the medial and lateral tibial condyles. However, when TKA prostheses are examined, they are mostly designed symmetrically. This symmetrical production approach is cost-oriented. However, when the postoperative disability and health problems are taken into consideration, the damages incurred may far exceed the the prosthesis production costs. This difference between the medial and lateral condyles must be taken into consideration when developing knee prostheses (18).

Tibial plateau width (IJ) was measured as 65.14±4.70 mm by Akdemir Aktaş et al. (4). Our IJ data were higher than those reported by Akdemir Aktaş et al. (4). Zalawadia and Patel (13) found the mean IJ value to be 70.78±2.40 mm. Our IJ data were lower than this study's data. The IJ value was found to be 67.91 mm, 70.2 mm, and 77 mm in the studies of Pradhan et al. (14), Bilkay et al. (15), and Shojaolsadati et al. (17), respectively. Our study's IJ value is 67.49 mm, which is lower than these studies'. The KL value of the intercondylar area was reported as 46.01±3.62 mm by Gandhi et al. (11) and 41.62±4.27 mm by Akdemir Aktaş et al. (4). While the KL value we found, 46.73 mm, was similar to that of Gandhi et al. (11), it was larger than that of Akdemir Aktaş et al. (4). The MN value of the intercondylar area at the anterior end was found to be 23.79 mm by Gandhi et al. (11) and 24.86 mm by Akdemir Aktaş et al. (4). We found the MN value to be 25.73 mm. IJ, KL, and MN measurements were consistent with the literature. It can be considered that standard production in prosthesis design does not make a significant difference for IJ, KL, and MN regions, and these regions are safe for complications.

The OP value of the intercondylar area in the middle narrow part was reported as 6.92 mm by Gandhi et al. (11), 21.27 mm by Akdemir Aktaş et al. (4), and 11.45 mm in our study. The RS value of the intercondylar area at the posterior end was reported as 6.92 mm by Gandhi et al. (11), was reported as 21.36 mm by Akdemir Aktaş et al. (4), and was reported as 15.76 mm in our study. Our OP and RS results were inconsistent with the literature data. Accordingly, OP and RS regions suggest that tibia dimensions may differ significantly regardless of ethnicity.

When comparing measurements between studies, the expected differences between CT and dry bone measurements were not evaluated separately. In addition, when we compare our data with the previous study of the Anatolian population, the differences can be attributed to the fact that Anatolia is located on a migration route due to its geopolitical position and is home to a mobile-heterogeneous population. However, the accessibility of dry bone is becoming increasingly difficult, and the absence of sex differences to account for data variability presents an important limitation. Tibial morphometric measurements are worthwhile for personalized prosthetic treatments.

Circle and TT length measurements in the proximal tibia have been evaluated in limited studies. In Pradhan et al.'s (14) study, the circle and TT length measurements were found to be 19.37 cm and 33.48 mm, respectively. While the circle value was compatible with our study, the TT length was found to be higher. According to our measurements, the mean circle was significantly greater than the mean TT length. Taking the circumference and TT length as the basis for designing prostheses will provide a more appropriate prosthesis for better adaptation to the tibia.

Study Limitations

A limitation of our study was the lack of age and gender data due to the dry bone method.

CONCLUSION

A better understanding of the anatomy of the proximal tibia is essential for the design of appropriate tibial prostheses. The average KL value of the intercondylar area, the OP value of the intercondylar area in the middle narrow part, and the RS value of the intercondylar area at the rear end, differ from those of the same population, supporting the necessity of a personalized prosthesis. Patient-specific prostheses may resolve incompatibilities soon. The difference between the anteroposterior and mediolateral dimensions of the medial and lateral condyles should be considered when designing knee prostheses. More comprehensive studies evaluating the proximal tibia with CT in terms of sex and age differences can be planned.

ETHICS

Ethics Committee Approval: It has obtained ethical approval from the Local Ethics Committee of Selçuk University (approval no: 2023/469, date: 13.10.2023).

Informed Consent: Since data for this study were obtained from the dry bone collection of our faculty, there is also no informed consent form.

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FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: B.P., Concept: Z.F., Design: Z.F., Data Collection or Processing: M.U., Analysis or Interpretation: B.S., B.P., Z.F., Literature Search: M.U., B.S., Writing: M.U.

Conflict of Interest: No conflict of interest was declared by the authors.

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