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Anatomical Features of the Proximal Femur in the Turkish Population

Características Anatómicas del Fémur Proximal en la Población Turca

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SUMMARY: Different populations have different genetic traits, and this causes various anatomical features to emerge. Orthopedic implants used in Turkey are generally of Western origin, and these implants are designed based on the anatomical features of Western populations. This study aimed to evaluate the compatibility of existing implants for the Turkish population by revealing the anatomical features of the proximal femurs of individuals from the Turkish population while also constituting a helpful source of data on newly developed implants. A total of 1920 proximal femurs of 960 patients were evaluated via images obtained by Computer Tomography. Twenty patients (10 females and 10 males) for each age within the age range of 18-65 years were included. Femoral head diameter, femoral neck width, femoral neck length, medullary canal width, and collodiaphyseal angle were measured.The right and left femoral head diameter was 46.46±3.84 mm, 46.50 ±3.85 mm respectively. The right and left femoral neck width was 30.63±3.4 mm, 30.85±3.29 mm respectively. The neck length was 94.62±8.33 mm for the right proximal femur, it was 94.75±8.19 mm for the left .The width of the medullary canal was 15.46±2.25 mm for the right proximal femur and 15.53±2.20 mm for the left. The right and left hips, the collodiaphyseal angles were 133.06±2.39° and 133.13±2.36°. Anatomical features of the proximal femur vary according to age, sex, and race. This study may be used as an important resource for the evaluation of patients' compatibility with existing implants and for the design of new implants.

KEY WORDS: Proximal femur; Femoral head diameter; Femur neck width; Femoral neck length; Collodiaphyseal angle.

INTRODUCTION

The proximal femur is very important anatomical region for orthopedic surgeons and surgeons perform to many surgical interventions (Sheehan *et al*., 2015). For this region, there are indications for surgery with different reasons such as trauma, tumor, deformity, arthrosis, and implants are applied. In general, the anatomical features of the proximal femur have been revealed in studies conducted with Western populations and implants were designed based on those measurements (Sengodan *et al*., 2017)..

Different societies have different genetic traits and this causes different anatomical features to emerge (Edwards *et al*., 2020). The diversity of interventions and implants applied to the proximal femur brings with it the necessity of knowing the anatomical features of this region better.

Current study aimed to examine the anatomical features of the proximal femur of the Turkish population radiologically and to reveal the results. The compatibility of existing implants for the Turkish population were evaluated and it is hoped that the success of orthopedic operations will increase with correct implant selection and that this study will provide important data for future work on newly developed implants.

MATERIAL AND METHOD

This study was carried out with the approval of the ethics committee of the relevant institution. Twenty patients (10 women and 10 men) for each age within the age range of 18-65 years were included in the study. A total of 1920 proximal femurs, right and left, of 960 patients were examined. Images of patients who had undergone Computed Tomography (CT) imaging of the pelvis for different reasons were used. Patients were not included in the study if they had developmental dysplasia of hip; fractures of the pelvis, acetabulum, or proximal femur; previous proximal femur

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surgery; hip osteoarthritis; or loss of the sphericity of the femoral head for any reason.

Five parameters were evaluated using the hospital's Picture Archiving and Communication Systems (PACS): femoral head diameter, femoral neck width, femoral neck length, medullary canal width, and collodiaphyseal angle (Fig. 1). These parameters were defined as stated below and the same methods were applied for all patients:

1. Femoral head diameter (FHD): The largest diameter in the section where the femoral head is largest
2. Femur neck width (FNW): The narrowest diameter perpendicular to the femoral neck axis
3. Femoral neck length (FNL): The distance between the apex of the femoral head and the lateral cortex on the femoral neck axis

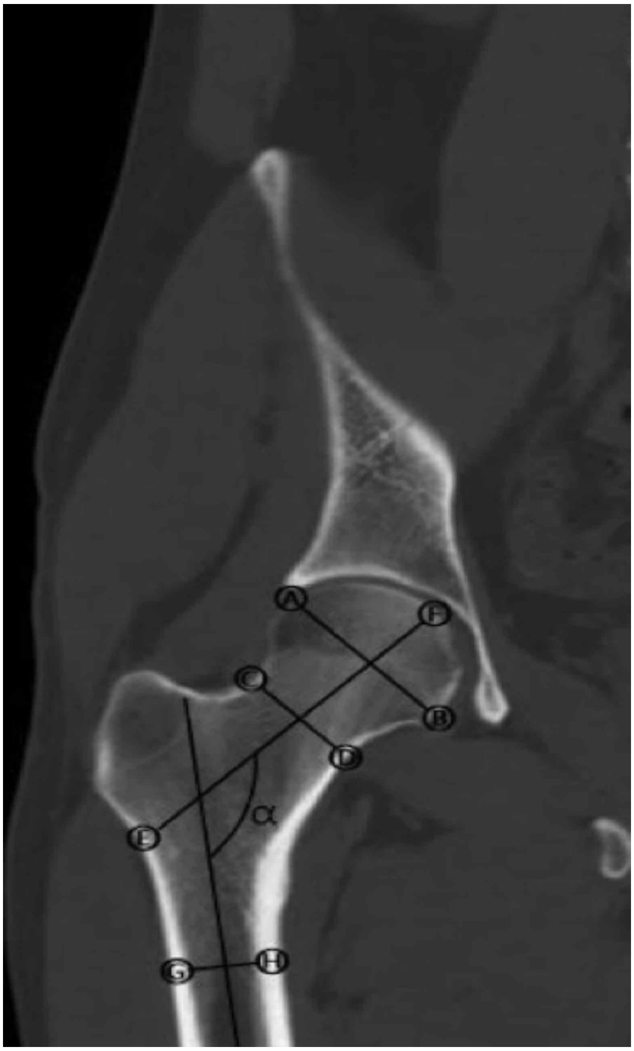

Fig. 1. Figure shows femoral head diameter (AB), femoral neck width (CD) , femoral neck length (EF), medullary canal width(GH), and collodiaphyseal angle (α).

4. Medullary canal width (MCW): Diameter of the femoral medulla 2 cm below the trochanter minor
5. Collodiaphyseal angle (CDA): Angle between the femoral shaft and the neck.

Images were obtained with a Philips Brilliance iCT device with 2-mm cross-sections while the patients were lying in the supine position. Evaluations of images were performed by an orthopedic physician and those results were checked. The results of the measurements were statistically evaluated and interpreted according to the differences between the sexes and the differences between right/left hips.

IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA) was used for statistical data analysis. Descriptive analyses were used to provide information about the sociodemographic and clinical characteristics of the groups. Continuous variables were shown as mean ± standard deviation. Student's t-test was used to determine the statistical significance of the differences between the sexes considering the arithmetic means of the continuous variables found to meet the parametric test conditions. In addition, paired t-tests were used for evaluating the statistical differences of the arithmetic means of continuous variables between dependent groups. The Pearson correlation coefficient was used to evaluate the relations among continuous variables. The type I error level was determined as 0.05.

RESULTS

The mean age of the patients participating in this study was 41.5±13.8 years. The obtained data were compared with the measurements made for right and left proximal femurs. The variation of the measured parameters with age was also examined. The mean values of the measurements for men and women are given in Table I.

Femoral head diameter: As a result of the measurements, the mean diameter of the right femoral head was measured 46.46±3.84 while the left femoral head diameter was measured46.50±3.85. There was no statistically significant difference between the diameters of the right and left femoral heads of these patients ($p=0.55$).

Femoral neck width: The right femoral neck width was measured 30.63±3.4, while the left femoral neck width was measured 30.85±3.29 mm. In the comparison made for right and left proximal femurs, it was seen that the left femur neck width was larger than that of the right and this difference was statistically significant ($p<0.01$).

Femoral neck length: In the measurements taken for both hips, the neck length was measured 94.62±8.33 mm for the right proximal femur and 94.75±8.19 mm for the left proximal femur. When the mean values of the femoral neck lengths were compared, it was observed that the left femoral neck was longer than the right, and this difference in neck lengths between the two sides was statistically significant (p=0.02).

Medullary canal width: Another measured parameter of the proximal femur was the medullary canal of the femur. While this value was 15.46±2.25 mm for the right proximal femur, it was 15.53±2.20 mm for the left. The width of the left medullary canal was found to be wider than that of the right side. The difference between the two sides in terms of medullary canal width was statistically significant (p<0.01). Collodiaphyseal angle: In the measurements made for the right and left hips, the collodiaphyseal angles were measured 133.06±2.39° and 133.13±2.36 °, respectively. When the collodiaphyseal angles of the two sides were compared, it was seen that this value was greater for the left femur than for the right, and this difference was statistically significant (p=0.003). The relationship between the measured parameters and age was examined, it was seen that there was no significant change in other parameters as the diaphyseal diameter increased with age. Correlation between age and parameters is shown in Table II.

Table I. The mean values of the measurements.

	Women				Men					
	N	Mean	SD. Deviation	SD. Error	N	Mean	SD. Deviation	SD. Error	t	p
Age	480	41.50	13.868	0.633	480	41.50	13.868	0.633	<0.01	1.00
Right Head Diameter	480	43.57	2.465	0.112	480	49.35	2.608	0.119	-35.311	<0.01
Right Neck Width	480	28.18	2.237	0.102	480	33.08	2.645	0.121	-30.979	<0.01
Right Neck Height	480	88.73	5.362	0.245	480	100.50	6.405	0.292	-30.862	<0.01
Right Collodiaphyseal Angle	480	132.86	2.409	0.110	480	133.27	2.373	0.108	-2.673	0.008
Right Diaphyseal Diameter	480	14.51	1.849	0.084	480	16.41	2.225	0.102	-14.356	<0.01
Left Head Diameter	480	43.64	2.558	0.117	480	49.37	2.616	0.119	-34.283	<0.01
Left Neck Width	480	28.56	2.219	0.101	480	33.13	2.529	0.115	-29.471	<0.01
Left Neck Height	480	89.00	5.257	0.240	480	100.49	6.386	0.291	-30.427	<0.01
Left Collodiaphyseal Angle	480	132.94	2.389	0.109	480	133.31	2.329	0.106	-2.381	0.017
Left Diaphyseal Diameter	480	14.63	1.797	0.082	480	16.43	2.207	0.101	-13.873	<0.01

Table II. Correlation between age and parameters.

Correlations			
	Age		
	r	p	N
Age	1		960
Right Head Diameter	0.151	<0.001	960
Right Neck Width	0.181	<0.001	960
Right Neck Height	0.234	<0.001	960
Right Collodiaphyseal Angle	-0.153	<0.001	960
Right Diaphyseal Diameter	0.458	<0.001	960
Left Head Diameter	0.157	<0.001	960
Left Neck Width	0.206	<0.001	960
Left Neck Height	0.234	<0.001	960
Left Collodiaphyseal Angle	-0.132	<0.001	960
Left Diaphyseal Diameter	0.441	<0.001	960

DISCUSSION

The proximal femur is very important anatomical region for orthopedic surgeons and surgeons perform to many surgical interventions (Sheehan *et al.*, 2015). For a successful surgery, first of all, careful preoperative planning is required, and this is only possible upon knowing the anatomical features of the region in which the operation will be carried out and choosing the implants to be applied in accordance with that region. Current study, the anatomical features of the proximal femur of the Turkish population were examined radiologically. CT was used as the radiological imaging method because it allows a more detailed examination of bones and joints, and measurements made with CT give more accurate information than direct radiography (Rubin *et al.*, 1992).

In the literature, there are various studies conducted among different populations to reveal the anatomical features of the proximal femur. Edwards *et al.* (2020) examined the anatomical features of the proximal femur according to race and sex in their study. Evaluating data from European Caucasians, American Caucasians, African Americans, and Chinese individuals, it was found that measurements differed between both races and sexes. The remarkable difference between European and American Caucasians was interpreted as being due to not only genetic factors effective in femoral anatomy but also the environment in which people live, which may have an effect on this issue (Edwards *et al*., 2020). Vetrivel *et al*., in their study evaluating the proximal femur features of people living in South India, compared the data they obtained with studies conducted for different regions of their country and they reported that their results were different (Sengodan *et al*., 2017). Considering that the anatomical features of the proximal femur can vary even from region to region in the same country, it is only possible to determine the anatomical features of a population through measurements made with members of that specific population. Turkey is a developing country with a large population, located between the continents of Europe and Asia. Aydin *et al*. (2016) conducted a study in which they examined acetabular-pelvic parameters in the Turkish population and evaluated only the collodiaphyseal angle in relation to the proximal femur. They did not measure or evaluate other parameters of the proximal femur (Aydin *et al*., 2016). The present study will contribute to the elimination of that lack of data.

Roughly 800,000 hip replacement surgeries are performed annually worldwide (Li *et al*., 2003). Choosing the right implants for hip replacement surgeries is important for achieving successful results. Therefore, femoral head size is important (Padgett & Warashina, 2004). In their study, Mokrovic *et al*. (2021) found the mean size of the femoral head to be 38.84 mm in the Croatian population. Vetrivel *et al*. reported a mean femoral head size of 42.6 mm in the study that they carried out in South India (Sengodan *et al*., 2017). In a study conducted with Chinese participants, Lin *et al*. (2014) measured the average size of the femoral head as 45.4 mm. In the present study, the right femoral head diameter was found to be 46.46±3.84 mm and the left femoral head diameter was 46.50±3.85 mm in the Turkish population. When compared with other populations, the average head diameter is seen to be larger in the Turkish population. This allows for the use of a larger femoral head. Large head diameter is a factor that increases the stability and range of motion of a hip prosthesis (Tsikandylakis *et al*., 2018). In this respect, it is thought that more stable hip replacement surgeries with greater ranges of motion can be performed in the Turkish population.

The incidence of hip fractures is increasing with the effect of extended life expectancy. It is anticipated that there will be 6.26 million hip fracture patients in the world in 2050 (Dennison *et al*., 2006). Although different implants, for example; Proximal Femoral Nail (PFN), Dynamic Hip Screw (DHS) and cannulated screws are used for the treatment of fractures in the trochanteric region and the femoral neck, an important common feature of these implants is the presence of a component that enters through the lateral cortex of the femur, passes the femoral neck, and ends in the femoral head. Therefore, femoral neck diameter and lateral cortex apex distance are important in the treatment of such fractures. Lin *et al*. (2014) found the mean femoral neck width to be 33.91 mm in their study. Vetrivel *et al*. reported that this value was 27.5 mm in South India (Sengodan *et al*., 2017). In the present study, the femoral neck width was found to be 30.63±3.4 mm for the right hip and 30.85±3.2 mm for the left hip in the Turkish population. In light of these values, methods and tools such as DHS, PFN, PFN-A, and cephalomedullary nails, which are currently used in fracture treatment, can be safely applied in the Turkish population. In addition, the issue that requires the most attention is femoral neck fractures. Generally, 6.5-mm cannulated screws can be used for fixation of femoral neck fractures. Fixation can be achieved with 3 or 4 screws (Rajnish *et al*., 2019). Considering the femoral neck widths of patients living in Turkey, it should be kept in mind that fixation with 4 screws may be difficult and may cause intraoperative complications, especially for female patients. The length of the implants inserted through the lateral cortex and extended to the neck is important in the pertrochanteric region and femoral neck fractures. Implants that are shorter than they should be and that do not cross the fracture line will not be sufficient for the fixation of the fracture, while longer implants will go from the femoral head to the hip joint and cause destruction of the hip joint. Baharuddin *et al*. (2011) found the mean femoral neck length to be 91.08 mm for men and 81.78 mm for women in Malaya. Edwards *et al*. (2020) reported neck length as 59.08 mm in men and 55.99 mm in women in their study. In research conducted among the Croatian population, Mokrovic *et al*. (2021) reported the femoral neck length as 44.29 mm. In the Turkish population, these values were measured as 94.62±8.3 mm for the right proximal femur and 94.75±8.1 for the left proximal femur. The most important reason for these differences in comparison to the studies of Mokrovic *et al*. (2021) and Edwards *et al*. (2020) is that the whole head was not included in the measurements of neck length in those two previous studies (Edwards *et al*., 2020; Mokrovic *et al*., 2021). However, there are many studies concluding that the implants used in the fixation of proximal femur fractures should be advanced to the subcapital region of the femoral head (John *et al*., 2019; Khanna & Tiwari, 2021). The measurements were made in this way in this study because it was thought that it would be important to know the entire distance from the lateral cortex of the femur to the apex of the head.

The proximal femur is an anatomical structure that transitions from the wide metaphyseal region to the diaphyseal region in a narrowing shape, and it has many anatomical variations (Mattesi *et al*., 2021). It has been shown that the success of hip joint reconstructions is closely related to implant design and that the diameter of the nail to be used is important for the union of femur fractures (Fessy *et al*., 1997). Consequently, it is important that the femoral components of hip prostheses be applied and the intramedullary nails be compatible with this region. Rubin *et al*. (1992) measured the mean femur diameter to be 21 mm at 2 cm below the trochanter minor. Umer *et al*. (2010) reported in their study that the mean value of the femoral diameter was 21.1 mm in the Pakistani population. Siwach *et al*. (2018) found the width of the medullary canal to be 16.57 mm in their study conducted with femurs of Indian people. In the present study carried out for the Turkish population, medullary canal width was found to be 15.46±2.25 mm for the right femur and 15.53±2.20 mm for the left femur. It is thought that this difference between other populations and the Turkish population may be due not only to anatomical features but also to different measurement methods, since other studies conducted measurements by X-Ray.

One of the important geometric measurements for the proximal femur is the collodiaphyseal angle. This angle between the femoral diaphysis and the neck must be within normal ranges to ensure proper alignment in the limb and to transfer the weight of the trunk to the limb correctly (Villette *et al*., 2020). In prosthesis placements incompatible with the collodiaphyseal angle, the load balance transferred to the femur via the femoral stem will be disturbed. These unbalanced loads will increase micromovements of the prosthesis and cause the prosthesis to loosen earlier than expected (Rawal *et al*., 2012). Implants used in proximal femur fractures are also designed with this angle. There are designs for 125°, 130°, 135°, and 140° collodiaphyseal angles for implants such as DHS and PFN. Choosing an implant compatible with the patient's anatomy will reduce implant failure rates and make fracture treatments more successful. Mokrovic *et al*. (2021) reported that they measured the collodiaphyseal angle as 125.34° in their study within the Croatian population. In their study in India, Rawal *et al*. (2012) found the mean value of this angle to be 124.42°. Lin *et al*. (2014) found the mean collodiaphyseal angle to be 129.88° in a study that included Chinese people. Husmann *et al*. (1997) reported that the mean value of this angle for French participants was 129.2°. In their study within the Turkish population, Aydin *et al*. (2016) measured the mean collodiaphyseal angle as 139.54° for the right femur and 138.42° for the left femur. In the present study, these values were found to be 133.06±2.39° for the right femur and 133.13±2.36° for the left femur in the Turkish population. It is thought that two factors were effective in the emergence of such different results among the Turkish participants in the study conducted by Aydin *et al*. (2016) and the present study. The first of these factors is the measurement method. In Aydin *et al*. (2016) study, some measurements were performed digitally and some were performed manually with a goniometer. The second factor is that their study was carried out as a multicenter study. When these two points are evaluated, it is thought that the results may have been affected due to insufficient standardization in imaging and measurements.

Our study was carried out with an equal number of patients of all ages between the ages of 18-65, we aimed to examine a homogeneous patient group. When the variation of the measured parameters according to age is examined, there is a statistical increase in the diameter of the femoral diaphysis with age. Many authors argue that large collodiaphyseal angle, femoral neck width, and femoral diaphysis width are risk factors for hip fracture in elderly patients (Gómez Alonso *et al*., 2000; Brownbill & Ilich, 2003). Our study does not include the patient group over 65 years of age. We think that this is the reason for the difference between our study and the literature.

The most important limitation of this study is that it was conducted in a single center. The study was carried out in Istanbul. Istanbul is a metropolis with a population of more than 15 million and it is the largest city in Turkey, receiving migration from all regions. It is thought that a multicenter study planned in different regions of Turkey can be subsequently designed to give more accurate results regarding the mean values of the Turkish population.

Anatomical features of the proximal femur vary according to age, sex, and race. Current study, the anatomical features of the proximal femur in the age range of 18-65 years in the Turkish population were presented. This study may serve as an important resource in the evaluation of patient compatibility with existing implants and the design of new implants.

KART, H.; SAHBAT, Y. & EROL, B. Características anatómicas del fémur proximal en la población turca. *Int. J. Morphol., 40(6)*:1524-1529, 2022.

RESUMEN: Diferentes poblaciones tienen diferentes rasgos genéticos, y esto hace que surjan varias características anatómicas. Los implantes ortopédicos utilizados en Turquía son generalmente de origen occidental y estos implantes están diseñados en función de las características anatómicas de estas poblaciones. Este estudio tuvo como objetivo evaluar la compatibilidad de los implantes existentes para la población turca al revelar las características anatómicas de las epífisis proximales de fémures de individuos de la población turca y, al mismo tiempo, constituir una fuente útil de datos sobre implantes recientemente desarrollados. Se evaluaron un total de 1920 fémures proximales de 960 pacientes mediante imágenes obtenidas por tomografía computarizada. Se incluyeron veinte pacientes (10 mujeres y 10 hombres) para cada edad dentro del rango de edad de 18 a 65 años. Se midió el diámetro de la cabeza femoral, el ancho del cuello femoral, la longitud del cuello femoral, el ancho del canal medular y el ángulo colodiafisario. El diámetro de la cabeza femoral derecha e izquierda fue de 46,46 ± 3,84 mm, 46,50 ± 3,85 mm, respectivamente. La anchura del cuello femoral derecho e izquierdo fue de 30,63±3,4 mm, 30,85±3,29 mm, respectivamente. La longitud del cuello fue de 94,62±8,33 mm para el fémur derecho, fue de 94,75±8,19 mm, para el izquierdo. El ancho del canal medular fue de 15,46±2,25 mm para el fémur derecho y de 15,53±2,20 mm para el izquierdo. Las caderas derecha e izquierda, los ángulos colodiafisarios fueron 133,06±2,39° y 133,13±2,36°. Las características anatómicas de la epífisis proximal del fémur varían según la edad, el sexo y la raza. Este estudio puede utilizarse como un recurso importante para la evaluación de la compatibilidad de los pacientes con los implantes existentes y para el diseño de nuevos implantes.

PALABRAS CLAVE: Fémur proximal; Diámetro de la cabeza femoral; Ancho del cuello femoral; Longitud del cuello femoral; Ángulo colodiafisario.

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