Radiological evaluation of the relationship between femoral head rotation center and trochanter major

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A- Conception and study design; B - Collection of data; C - Data analysis; D - Writing the paper; E- Review article; F - Approval of the final version of the article; G - Other (please specify)

ABSTRACT

Purpose: We aimed to investigate the distance between the tip of Trochanter Major (TTM) and the Femoral Head Rotation Center (FHC) and investigate other measurements on orthoroentgenograms obtained in the local population.

Materials and methods: Patients aged 18 and over who were admitted to the hospital between 2 June 2020 and December 2020 and had an orthoroentgenogram were included in the study. Patients with hip joint degeneration, deformities, bone dysplasia, bone tumors, bone tissue irregularities, old fractures or surgical findings, and those with lower extremity length discrepancies were excluded from the study. The tip of trochanter major - The femoral head rotation center (TMFH) distance, collodiaphyseal angle, femur length, and femoral head area were measured on the orthoroentgenogram. Radiological measurements were made by two orthopedic specialists who participated in the study. In addition, the age and gender of the patients and the side of the femur evaluated were recorded.

Results: When evaluated according to gender, it was observed that the femoral length of the males was approximately 35.37 ± 5.6+3 mm longer than that of the females, and the femoral head area was 3 ± 1.4 cm² larger compared to the females (Table 1). These differences between the genders were considered statistically significant (<0.001). The mean collodiaphyseal (CD) angle of 180 femurs included in the study was 131.9° ± 5.2°, the TMFH distance was measured as 4.77 ± 5.0 mm, the tip of trochanter major was above the femoral head rotation center. There was no statistically significant difference in this distance in terms of gender and mean right/left side measurements.

Conclusions: The relationship between the femoral head rotation center (FHC) and the tip of the trochanter major (TTM) is a viable method in determining the lower extremity length. While evaluating this relationship, the values of the non-affected contralateral hip can be used. However, if any deformity in the contralateral hip occurs, measurements obtained in the local population could be helpful in providing information about appropriate leg length.

Keywords: Hip reconstruction, anthropometry, proximal femoral anatomy, femoral head rotation center, trochanter major

DOI

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INTRODUCTION

Evening out the leg lengths is one of the most important parts of surgery as it affects the functional result in hip arthroplasty [1]. It is suggested that the leg length difference should be less than 1 cm [2]. This situation can lead to problems such as back pain, dislocation, and gait disturbance. In addition, an impingement between the acetabulum and the proximal femur may cause dislocation of the total hip replacement [3-5]. The relationship between the trochanter major and the femoral head center is one of the methods used in the determination of the normal anatomy of the proximal femur [6]. This relationship is a parameter that can be used during surgery to decide on the length of the extremity while performing total hip arthroplasty [6,7]. In addition, it can be used during hip reconstruction while performing methods such as k-wire insertion into the infracotyloid groove, L-shaped calipers, ischial tubercle, and the relationship between trochanter minor and femoral head with tear drop. However, these methods can be affected by situations such as the position of the patient and the position of the operating table [2,8-12]. Although stenciling methods are used, it is argued that it is not a reliable enough method to restore the length of the extremity [13]. Although there are intraoperative navigation techniques, these methods are not widely used due to difficulties in learning the method and accessing this method [14].

Among many described methods of total hip arthroplasty surgery, a surgeon should use the most comfortable and valid method. These methods may have superiority over each other during surgery. The specified parameters should not change depending on the patient’s position and imaging method. Rotation of the femur, the position of the pelvis and femur relative to each other can alter the criteria. The tip of trochanter major is not affected by femoral rotation. The vertical distance between the trochanter major and the femoral head is a criterion that can be evaluated easily and effectively in ensuring the extremity length during surgery [6]. For this evaluation, the contralateral hip, which is on the opposite side of the hip where arthroplasty is performed, should be in normal anatomy. Otherwise, the data of the population with normal anatomy are needed [15-17]. For this reason, whether the relationship between the trochanter major and the femoral head rotation center is different from the opposite hip and the normal values of the local population should be known.

In this study, we aimed to investigate the distance between the tip of Trochanter Major (TTM) and the Femoral Head Rotation Center (FHC) and investigate other measurements on orthoroentgenograms obtained in the local population.

MATERIALS AND METHODS

The mean age of 90 people included in the study (Male: 45, Female: 45) was 43.8 ± 16.7. The study was conducted in a tertiary hospital located in Turkey. The study was conducted by two orthopedic specialists between January 2021 and February 2021. Patients aged 18 and over who were admitted to the hospital between June 2020 and December 2020 and had both sides orthoroentgenograms were included in the study. The entire femur, including its proximal and distal parts, was evaluated from the orthoroentgenogram obtained. Patients with hip joint degeneration, deformities, bone dysplasia, bone tumors, bone tissue irregularities, old fractures or surgical findings, and those with lower extremity length discrepancies were excluded from the study. On the orthoroentgenogram, a line was drawn parallel to the femoral axis dividing the femur medulla in the middle. Then, a circle was drawn to best fit the femoral head. The center of this circle was determined as FHC. A line perpendicular to the line dividing the femur medulla in the middle was drawn in a way passing through TTM. Another line perpendicular to the same line was also drawn in a way passing through FHC. The distance between these two lines drawn perpendicular to the line dividing the medulla into two equal parts was measured. This value shows the TMFH distance (Figure 1). In addition, femur length, colli-diaphyseal angle, and femoral head area were measured on both sides. Other than these, no other measurements were made. Two orthopedic specialists who participated in the study did not make radiological measurements independently. The age and gender of the patients included in the study, and the side of the femur evaluated was recorded.

In our study, the errors that can be made during measurement were minimized by performing the measurements in a software program. In addition, patients with completely normal hip joint anatomy were evaluated in the study, and the normal population values were obtained.

For this study, the ethics committee approval from the university of Nevşehir Hacı Bektaş Veli and necessary institutional permissions were obtained.

Statistical analysis

Data were analyzed using the SPSS 22.0 program. After analyzing conformity of variables to normal distribution with the Shapiro-Wilk test, unpaired and paired t-tests were used in the analysis of quantitative variables. The relationship between the variables was analyzed with Pearson’s correlation test, and the results below the p-value of 0.05 were considered statistically significant.
Ethical Considerations
For study implementation, ethics committee approval numbered 2020.09.71 was obtained from the ethics committee of the university of Nevşehir Hacı Bektaş Veli (Turkey).

RESULTS
These differences between the genders were considered statistically significant (<0.001). The mean collodiaphyseal angle of 180 femurs included in the study was $131.9^\circ \pm 5.2^\circ$, and the TMFH distance was measured as 4.7±5.0 mm. There was no statistically significant difference in this distance between gender and mean right/left side measurements (Table 1).

When evaluated according to gender, it was observed that the femoral length of the males was 35.17±5.36 mm longer than that of the females, and the femoral head area was 3±1.4 cm$^2$ larger compared to the females (Table 1).

There was a weak correlation between age and femur length ($r$: -0.388) and TMFH distances ($r$: 0.176), and a strong correlation between TMFH and collodiaphyseal angle ($r$: -0.611) (Table 2).
Table 1. The distribution of femoral length, head area, collodiaphyseal angle, and distance between the tip of trochanter major and femoral head rotation center by genders and sides. (Results shown as mean±SD)

<table>
<thead>
<tr>
<th></th>
<th>Male (n=90)</th>
<th>Female (n=90)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Femur Length (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>442.8 ± 30.7</td>
<td>405.6 ± 40.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left</td>
<td>443.5 ± 30.7</td>
<td>410.0 ± 25.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Difference between sides</td>
<td>0.215</td>
<td>0.323</td>
<td></td>
</tr>
<tr>
<td><strong>Femoral Head Area (cm²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>19.4 ± 2.8</td>
<td>15.7 ± 2.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left</td>
<td>19.2 ± 2.5</td>
<td>15.7 ± 2.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Collodiaphyseal Angle (°)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>132.6 ± 4.9</td>
<td>131.8 ± 4.8</td>
<td>0.475</td>
</tr>
<tr>
<td>Left</td>
<td>131.9 ± 4.9</td>
<td>131.4 ± 5.5</td>
<td>0.703</td>
</tr>
<tr>
<td>Difference between sides</td>
<td>0.050</td>
<td>0.440</td>
<td></td>
</tr>
<tr>
<td><strong>TMFH Distance (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>4.9 ± 5.6</td>
<td>4.0 ± 4.5</td>
<td>0.398</td>
</tr>
<tr>
<td>Left</td>
<td>4.9 ± 5.0</td>
<td>4.9 ± 4.9</td>
<td>0.989</td>
</tr>
<tr>
<td>Difference between sides</td>
<td>0.970</td>
<td>0.103</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Correlation table between age, femur length, head area, collodiaphyseal angle, and distance between the tip of trochanter major and femoral head rotation center

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Femur Length</th>
<th>Femoral Head Area</th>
<th>Collodiaphyseal Angle</th>
<th>TMFH Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>**-0.388</td>
<td>-0.006</td>
<td>-0.132</td>
<td>*0.176</td>
<td></td>
</tr>
<tr>
<td><strong>Femur Length</strong></td>
<td>**0.610</td>
<td>*0.159</td>
<td>-0.131</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Femoral Head Area</strong></td>
<td>-0.031</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collodiaphyseal Angle</strong></td>
<td></td>
<td></td>
<td></td>
<td>**-0.611</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

In hip arthroplasty applications, various methods such as the relationship between the trochanter major and the femoral head center, k-wire insertion into the infracotyloid groove, L-shaped calipers, ischial tubercle, and the relationship between trochanter minor and femoral head with teardrop that can be applied before and during surgery to determine leg length [11-14,18,19]. Although there are differences between these methods, discussions continue about which method is the best [15].

The effectiveness and applicability of these methods are important because of the complications that may occur after the surgery and patient satisfaction [20]. Discrepancies of more than 2 cm that may occur after surgery can result in pain, dislocation, and gait disturbance [2-5].

Assessment of the TMFH distance is a viable method that can be used intraoperatively in hip reconstruction surgeries [21]. Using this method intraoperatively makes it possible to create the appropriate anatomy, muscle balance, required offset, and leg length in hip arthroplasty [21,22]. When using this method, the distance between FHC and TTM should be determined according to the contralateral hip or the normal population data. Having TTM at the same level with FHC during surgery may not always give the correct result. It is important to know the mean values of the local population, as it may not always be a normal contralateral hip joint. In this study, when the right and left hips were compared, the distance was 4.9 ± 5.6 mm on the right side and 4.9 ± 5.0 mm on the left side in men, while it was 4.0 ± 4.5 mm on the right side and 4.9 ± 4.9 mm on the left side in women. There was no statistically significant difference between TMFH distances in the right and left hips. In addition, no statistically significant difference was
found between men and women. In the local population, the mean TMFH distance was found as 4.7 ± 5.0 mm, and TTM was higher than FHC. In Indian society, this value was found to be a mean value of 9.2 mm [21]. Morphometric studies of the proximal femur have been performed in Turkish society in various studies [23,24]. Proximal femoral parameters described by Noble et al. have also been measured in the Turkish population, but no study evaluating the TMFL distance has been found [23-25].

Various authors have conducted studies investigating the TMFH distance in various populations. While the results obtained in this study are similar to Ummaruntana et al. and Theivendran et al., they differ from some other studies [6,15-17, 26]. The differences between the studies may be due to the differences in the methods used in the studies, the differences in the mean age of the patients, as well as the anatomical differences between the societies. Therefore, when deciding on the appropriate position of the reconstruction procedure during surgery, normal values of the local population become an important factor if the opposite side could not be evaluated. Accordingly, it is thought that interracial variation should be considered in the intraoperative evaluation during hip surgery.

In our study, similar values were observed in the contralateral hips. As in previous studies, it was observed that the TMFH as substantially congruous with the TMFH of the contralateral hip [15,21]. In the study conducted by Dhosna et al., a significant correlation was found between the right and left sides, and it was reported that planning could be made according to the contralateral hip, especially in hip surgeries performed after trauma [15]. No statistically significant difference was found between hip TMFH distances on both sides. Accordingly, the restoration of the surgically performed hip can be performed according to the parameters of the contralateral hip. It may be difficult to detect the trochanter minor on an internally rotated femoral X-ray or in patients with rotational deformities. In such cases, the location of the TTM can be easily observed. In this way, the distance between FHC and TTM, which does not change with the patient position, is a reliable method for determining leg length. However, attention should be paid in patients who do not have normal hip anatomy on the opposite side. Care should be taken when an evaluation is made in cases such as hip circumference fractures and dysplasia, where difficulties are experienced in determining the actual locations of FHC and TTM. In addition, when assessing such cases, other methods will also help resolve inconsistencies that may occur. A similar study was done on using computer tomography (CT) [15].

Evaluation of this distance with CT gives quite accurate results. That is why the so-called CT protocol (low-dose: ~0.97 mSv) is widely used for research purposes. But in our country (Turkey), CT is not performed for every patient scheduled for surgery as it is a costly imaging method. Therefore, although it is a limitation that this study was not performed with CT, it is thought that it is more feasible to evaluate orthoro-roentgenogram.

While there was no significant difference between the right and left sides of the hip in terms of femoral head area, it was found that there was a significant difference between the genders. In the study of Acar et al., a significant difference was found between the right and left sides of the hip in terms of femoral head in both genders [24]. Accordingly, during surgical planning, it should be prepared to take into account the gender of the patient.

The mean collodiaphyseal angle was found to be 131.9° ± 5.2°, and there was no statistically significant difference between collodiaphyseal angle values in terms of genders and sides of the hip. Similarly, Acar et al. did not find a statistically significant difference between the sides of the hip and genders [24].

A strong negative correlation was found between CD angle and TMFH. When evaluated according to the level of ttm; People with a high CD angle may have a higher rotation center of the femoral head. Accordingly, the TMFH distance can be measured lower. Previous studies have shown a decrease in CD angle with age [27,28].

Similarly, a negative correlation was found between age and the CD angle in this study. The decrease can explain the positive correlation between age and TMFH in the CD angle with increasing age. While the CD angle decreases with age, decreasing the CD angle increases the distance between TMFH. Similar to the results obtained in the study of Prasad et al. [29], it was determined in this study that the CD angle increased as the femur length increased, and it was thought that the decrease in the distance between TMFH with increased femur length might be related to the increase in the CD angle due to the increase in femur length. Since there is a negative correlation between CD angle and TMFH, when performing hip surgery according to TMFH distance. It should be considered that the TMFH distance may be shorter in people with a high CD angle and that the TMFH distance may be longer in people with a low CD angle.

Hussein et al. examined femoral morphologies in various societies and reported important variations between femur lengths [30]. In our study, while there was no statistically significant difference between femur lengths in terms of hip sides, it was found that there was a significant
difference in terms of genders. As in the study of Hussein et al., while using these data in gender determination in the field of forensic medicine, the mean values of the femur length should be taken into consideration during orthopedic surgeries, both for reconstruction and during surgical preparation according to the nature of the surgery to be performed [30].

Among the limitations of this study, there may be difficulties in making these measurements in dysplastic hips and hip circumference fracture sequelae, where the femoral head rotation center is difficult to detect. In addition, the research was carried out in orthopedics and traumatology departments in only one region. For this reason, the results obtained in the research are limited to participants in this sample group.

CONCLUSIONS

During procedures related to the hip joint, especially in arthroplasty procedures, the relationship between FHC and TTM should be considered incorrectly determining the length of the lower extremity. While evaluating this relationship, one can benefit from the values of the healthy contralateral hip. However, in case of any deformity of the opposite hip, the mean values of the population will be useful in providing an appropriate leg length. Therefore, caution should be taken in patients with hip deformities on both sides, and an additional evaluation method should be used if necessary.

As a result, the TMFH distance was found to be 4.7 ± 5.0 mm in the Anatolian population, and it was observed that this distance was higher in men than in women. In our study, the mean CD angle in men was 442.8 ± 30.7 on the right, 443.5 ± 30.7 on the left; for women, it was 405.6 ± 40.6 on the right side and 410.0 ± 25.4 on the left. Femoral head area in men was 19.4 ± 2.8 on the right, 19.2 ± 2.5 on the left; in females, it was 15.7 ± 2.4 on the right and 15.7 ± 2.3 on the left. CD males were 132.6 ± 4.9 on the right, 131.9 ± 4.9 on the left; in females, it was 131.8 ± 4.8 on the right side and 131.4 ± 5.5 on the left side.

Conflicts of interest
There is no conflict of interest declared by the authors.

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REFERENCES


