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The effects of shoulder and hip widths on the acetabular angle in hip arthroplasty performed in the lateral decubitus position. Trochanter/shoulder ratio effect on postop inclination

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Abstract

Aim: This study aimed to determine the effects of the soft tissue and bone widths of the patient's hip and shoulder region on the patient's position and postoperative acetabular inclination angles in the lateral decubitus position during hip replacement procedures.

Materials and Methods: Seventy-three patients with primary coxarthrosis who underwent primary hip arthroplasty by a single experienced surgeon using a water gauge assisted inclinometer in lateral decubitus position were retrospectively studied. Soft tissue and bone widths of the shoulder, ASIS (Anterior superior iliac spine), and trochanter levels measured from the preoperative radiographs of the patients and shoulder/hip (ASIS-trochanter) ratios were calculated and made statistical comparisons with postoperative acetabular inclination angle.

Results: Postoperative inclination angle had a strong negative correlation with trochanter/shoulder soft tissue ratio, a moderate negative correlation with ASIS/shoulder soft tissue ratio, and a weak negative correlation with trochanter and ASIS/shoulder bone ratios. When patients are grouped by trochanter/shoulder ratio, the postoperative inclination value is 43.04 (38-47) degrees in the group with the ratio < 0.85, the postoperative inclination value is 38.67 (33-45) degrees in the group with the ratio of 0.85-1, and the mean postoperative inclination value in the group with the ratio > 1 was found to be 35.60 (30-38) degrees. ($p < 0.001$) As for the postoperative inclination values, the mean trochanter/shoulder and ASIS/shoulder values in the group with < 40 degrees were 0.99 and 0.94, respectively, while these values in the group with > 40 degrees were 0.83 and 0.79, respectively. ($p < 0.001$).

Conclusion: Soft tissue widths in the shoulder and hip regions may affect the surgical position and postoperative acetabular inclination angle. Knowing the relationship between the patient's preoperative hip and shoulder distance can influence the expected clinical outcome after hip arthroplasty. Therefore, surgeons should consider these effects when planning hip arthroplasty surgery.

Introduction

Success after total hip arthroplasty (THA) is primarily associated with the correct placement of the acetabular component. Postoperative dislocation, surface abrasions, limitation of the joint range of motion, loosening, and component migration may occur due to errors made in the positioning of the acetabular component. In THA, acetabular component positioning continues to be the most challenging and technically varied part of surgery [1-6]. Lewinnek et al. reported that an acetabular anteversion of 15 ± 10^0 and an inclination of 40 ± 10^0 were safe in preventing postoperative dislocation. Although acetabular safe zones differ according to the spinopelvic dynamics, the general opinion is that these angles provide sufficient stability [6,7]. However, during THA, there may be some difficulties in achieving the targeted acetabular inclination and anteversion, particularly in the lateral decubitus position. Surgical experience is an essential factor, but the orientation of the acetabular component often depends on the pelvic posture [8]. The posture of the pelvis is related

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Table 1. Comparison of postoperative inclination values between gender groups.

	Postop inclination angle(IQR)				
	min	mean	median	max	IQR
Male (n:23)	39°	42.82°	42°	47°	2.50°
Female (n:50)	30°	37.94°	37.50°	47°	5.75°

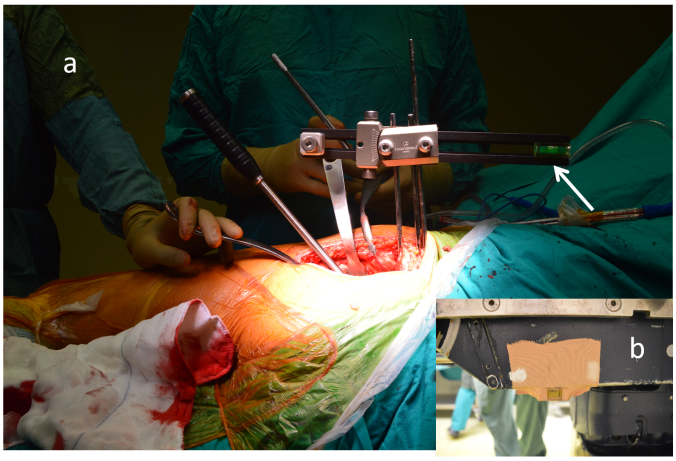

Figure 1. a. Apparatus used to determine the inclination angle of the acetabular component (the spirit level is shown by the white arrow).
b. Confirming that the table is parallel to the floor before the operation.

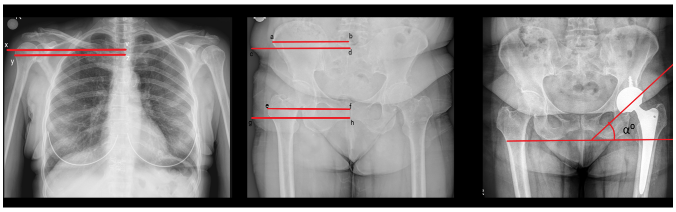

Figure 2. Preoperative and postoperative measurements of radiograps.
x-v The distance between the thoracic vertebral spinous process and the humerus tuberculum majus on the non-operated hip side (shoulder bone distance).
y-x The distance between the soft tissues at this level (shoulder soft tissue distance).
a-b The distance between the L5 or S1 vertebra spinous process at the ASIS level and the ASIS on the non-operated hip side (ASIS-bone distance).
c-d The distance between the soft tissues at this level (ASIS-soft tissue distance).
e-f The distance between the symphysis pubis and the greater trochanter on the non-operated side (trochanter bone distance).
g-h The distance between the soft tissue shadows at this level (trochanter soft tissue distance).
$\alpha°$ The postoperative inclination angle on the postoperative pelvis radiograph.

to the operating table and the position of the patient [8,9]. Soft tissue thickening around the hip can cause a misalignment of the pelvic position and cause difficulty in achieving the targeted acetabular inclination. Many techniques have been suggested in the literature for the adjustment of acetabular inclination to ensure standardization in surgical methods and to apply the surgical procedure accurately and efficiently by all surgeons. Traditional methods usually involve a rod, spirit level, water gauge, or digital device attached to the driving apparatus at a fixed angle [10-14]. The main problem in using these tools is related to taking the plane off the ground or the operating table as the basis for the measurement. However, the patient's pelvis lying in the lateral decubitus position cannot always be fully vertical due to factors such as patient height, body mass index (BMI), gender, shoulder width, pelvis width, leg diameter, and hip thickness [10, 11]. Many studies in the literature show changes in intraoperative and postoperative hip inclinations in THA performed in the lateral decubitus position. Still, there is no research investigating the effects of patients' pelvis and shoulder bone and soft tissue widths on their surgical position. In this study, we performed preoperative direct radiographs of the pelvis and chest from the bones and soft tissues of the humerus tuberculum majus, femur trochanter major, and anterior superior iliac spine (ASIS) points, which are the endpoints that touch the table in the lateral decubitus position and which we think affect the patient's position. We investigated the possible effects that may impact the patient's position and indirectly on the cup inclination to be determined during surgery. We hypothesized that the shoulder and pelvis's bone and soft tissue thicknesses affect the patient's position and correlate with acetabular inclination. To the best of our knowledge, no study to date has addressed the relationship between postoperative acetabular inclination angles of the measurements and ratios from the hip and shoulder regions of patients using preoperative radiographs.

Material and Methods

The study was carried out with the permission of the Gaziosmanpaşa Training and Research Hospital Clinical Research Ethics Committee (Date: 23.09.2020, Decision No: 130). A total of 255 patients who underwent primary THA in our clinic between 2013 and 2016 were retrospectively reviewed. Those in which the posterolateral approach and lateral decubitus positioning were used were identified. Of these cases, 204 had appropriate preoperative and postoperative radiographs of the pelvis and chest to measure soft tissue shadows. To standardize preoperative pelvic and chest radiographs, patients with femoral neck fractures in which standing preoperative radiographs were not possible (n=24), patients with developmental hip dysplasia (n=31), patients with spinal or hip disorders causing pelvic obliquity, and patients with previous spinal fusion surgery (n=30), patients with a history of previous hip-shoulder surgery (n=13), and cases in which surgeons had performed surgery on their learning curve or without using a method to determine hip tilt angle (n=29) were excluded from the study. Thus, retrospective measurements were performed on the preoperative and postoperative radiographs of 73 patients with primary coxarthrosis. Fifty (68.5%) patients were female, and 23 (31.5%) were male. The mean patient age was 54.66±10.35 (range 34 to 88) years. The operation was performed on the left side for 42 hips and the right for 31 hips. The surgeries were performed by a single experienced surgeon with a posterolateral approach in the lateral decubitus position and using a spirit level-assisted inclinometer to determine the inclination for placement of the cementless acetabular component. Spirit level assisted inclinometer designed by the lead surgeon. In all cases, another spirit level was used to verify that the table was positioned parallel to the floor before surgery. (Figure 1) All radiographs were performed using the "Drgem Diamond 6 A Automatic Collimator - 2013 (DRGEM Co., Ltd, South Korea) unit." The patient was placed on PA chest radiography with the anterior chest wall leaning against the cassette. According to the patient's condition, the technical values were set to 60-80 Kv 20-30mAs, and the exposure was performed. Next, the patient was placed standing, with the back of the cassette, the middle beam directed at the midline of the pelvis, and a focal distance of 150 cm in the pelvic radiography. The technical parameters were set according to the patient as 75-85 Kv, 25-35 mAs, and the exposure was performed. Imaging and measurements were performed using the ExtremePacs 2017 © General Radiology web interface. The following measurements were taken from the patients' preoperative AP pelvic and chest radiographs; the distance between the thoracic vertebral spinous process and the humerus tuberculum majus on the non-operated hip side (shoulder bone distance) on the preoperative lung posterior-anterior (PA) radiograph; and the distance between the soft tissues at this level (shoulder soft tissue distance); the distance between the L5 or S1 vertebra spinous process at the ASIS level and the ASIS on the non-operated hip side (ASIS-bone distance) and the distance between the soft tissues at this level (ASIS-soft tissue distance); the distance between the symphysis pubis at the greater trochanter level and the greater trochanter on the non-operated side (trochanter bone distance) and the distance between the soft tissue shadows at this level (trochanter soft tissue distance); and the postoperative inclination angle on the postoperative pelvis radiograph. (Figure 2).

Using the measurements on the preoperative radiographs, which we assume influence the pelvic orientation of the patient in the lateral decubitus position, the following ratios were calculated:

- Trochanter/shoulder soft tissue ratio: proportion of the trochanter soft tissue distance to the shoulder soft tissue distance
- Trochanter/shoulder bone ratio: proportion of the trochanter bone distance to the shoulder bone distance
- ASIS/shoulder soft tissue ratio: proportion of the ASIS soft tissue distance to the shoulder soft tissue distance
- ASIS/shoulder bone ratio: proportion of the ASIS bone distance to shoulder bone distance.

THA was performed with a posterolateral incision in all patients. The patients were placed perpendicular to the table with lateral support pads in the lateral decubitus position. A spirit level was used to confirm that the operating table was parallel to the ground. The lower hip and knee were flexed. A pillow was placed between the legs. The hip joint was accessed with a standard posterolateral approach. A femoral neck cut was made, and the acetabulum was exposed. The transverse acetabular ligament was visualized and using a marker pen. A line was drawn in the acetabulum, perpendicular to the ligament from the midpoint of the ligament. In the projection of this line, two or three Schanz pins were advanced to about 3 cm superior to the acetabulum with the aid of a surgical motor. The adaptation of the Schanz pins also helped to retract the upper part of the acetabulum without enlarging the incision. The apparatus for determining inclination was adapted for these pins. The water gauge on the spirit level over the device was aligned parallel to the ground. The acetabulum was carved, carefully keeping the indicator rod set at 40^0 inclination. An acetabular shell and acetabular component of appropriate size were placed parallel to the indicator rod, and following proper anteversion, the acetabular cup was hammered into position (Fig. 1). Then, an acetabular insert was placed, and the surgeon moved to the femur. After the femur was scraped with suitable rasps, an appropriate-sized femoral stem was hammered into the medulla without cement. After confirming stability, the stem was adapted for the femoral head, and the hip was reduced. A hemovac drain was placed, and after bleeding control and washing, the layers were closed according to the anatomical plane, and the operation was terminated. (Figure 1) The statistical analyses were performed using R 4.0.0 and RStudio version 1.3.959. The distributions were analyzed with the Shapiro-Wilk and Kolmogorov-Smirnov tests. Variance homogeneity was examined using the Levene test. As descriptive statistics, frequencies (n) and percentages (%) were used for categorical variables and median and interquartile ranges (IQR) for those that did not conform to normal distribution. The dependent t-test and independent t-test were used to fit a normal distribution when comparing numerical data. At the same time, the Mann-Whitney U test was employed when the data were not normally distributed. The Spearman correction was applied to the values that did not comply with the normal distribution in calculations concerning correlations. The correlations were evaluated as very strong if the value was above 0.90, strong if 0.70-0.90, moderate if 0.50-0.70, and weak if 0.30-0.50. Analysis of variance was used in multigroup comparisons and the Welch test in the absence of variance homogeneity. The significance level was accepted as $p < 0.05$.

Results

Considering the postoperative inclination angles between males and females, it was found that the mean inclina-

Table 2. Comparison of gender and postoperative inclination values.

Group	a	b	c	p value
Trochanter/shoulder soft tissue ratio	<0.85 n=24	0.85-1 n=34	>1 n=15	
Gender	(8F/16M) 33.33% F	(27F/7M) 79.41% F	(15F) 100%F	p<0.001
Mean postoperative inclination angle	43.04°(38°-47°)	38.67°(45°-33°)	35.60°(30°-38°)	p<0.001
±5° difference	4 patients over 45° No patients under 35° (16.66%)	No patients over 45° 3 patients under 35° (8.88%)	No patients over 45° 5 patients under 35° (33.33%)	p<0.001

Between groups according to the trochanter / shoulder soft tissue ratios.

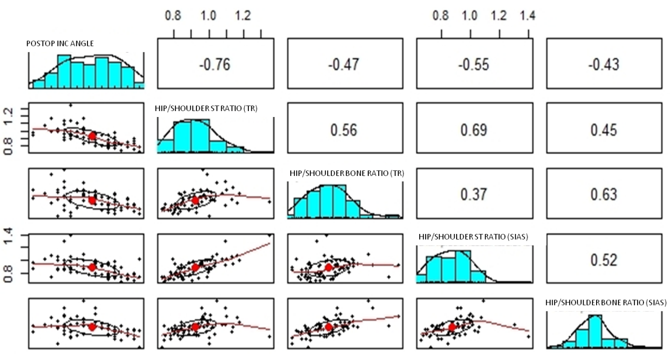

Figure 3. The correlation graph of the rates calculated based on the measurements with the postoperative inclination values.

tion angle was 42.82º in male patients and 37.94º in females. The mean inclination angle between the groups is statistically different. ($p < 0.001$) (Table 1). As for the relationship between postoperative inclination angle and trochanter/shoulder soft tissue ratio, the coefficient showed a strong correlation (-0.76). This indicates that the inclination angle increased when the trochanter/shoulder soft tissue ratio decreased in the studied sample. The correlation coefficient between postoperative inclination angle and trochanter/shoulder bone ratio was -0.47, indicating a weak negative relationship between the two parameters. In addition, postoperative inclination angle had a moderate negative correlation with ASIS/shoulder soft tissue ratio (-0.55) and a weak correlation with ASIS/shoulder bone ratio (-0.43). (Figure 3) Since the correlation coefficient was high, patients were divided into three groups according to their trochanter/shoulder ratio. Patients with trochanter/shoulder soft tissue ratio below 0.85 were classified as group A, between 0.85-1 as group B, and above 1 as group C. The postoperative inclination value of group A was 43.04 (38-47), the postoperative inclination value of group B was 38.67 (33-45), and the average postoperative inclination value of group C was 35.60 (30-38) degrees. The postoperative inclination angles between the groups were statistically significantly different ($p < 0.001$) (Table 2). When our patients were divided into < 40-degrees and > 40 degrees' groups according to their postoperative acetabular inclination angle values, the average soft tissue distances from the trochanteric level were 210.731 mm(SD=20.47), and the soft tissue distances at the ASIS level were 199.195 mm(SD=21.73) in the ≤40 degrees group, in the group with > 40 degrees, the mean trochanter soft tissue distances were 192.843mm(SD=11.21), while the ASIS soft tissue distance was 182.531mm(SD=21.13). ($p < 0.001$) (Table 4) Finally, regarding the postoperative inclination values, the mean trochanter/shoulder and ASIS/shoulder values in the ≤ 40-degree group were 0.994(SD=0.1) and 0.942(SD=0.12), respectively, while these values in the > 40 degree group were 0.835(SD=0.06) and 0.799(SD=0.1), respectively. ($p < 0.001$). (Table 3)

Discussion

Many surgical positions and approaches have been described in THA surgery. Changes in patient position and surgical approach significantly impact the surgical technique and outcomes [15]. Lateral decubitus positioning and posterior surgical approach constitute one of the most preferred approaches in THA performed today. In our patients, we used the lateral decubitus position and posterior approach during the surgical procedure. In clinical practice, it is often accepted that the patient's pelvis placed in the lateral decubitus position would also be in the full lateral position; however, this may not be valid in all cases. Hayakawa et al. [16] compared the intraoperative and postoperative anteroposterior radiographs of 100 THA cases performed in the lateral decubitus position. They reported an average deviation of 5.3^0 in the acetabular inclination angle and a variation of more than 10^0 in

Table 3. Comparison of soft tissue diameters in hip region and hip/shoulder soft tissue ratios when the sample is grouped by postoperative acetabular inclination angle.

Groups	≤40° n=41	>40° n=32
Soft tissue distance trochanter level(mm)	210.731(SD=20.47)	192.843(SD=11.21)
Soft tissue distance ASIS level(mm)	199.195(SD=21.73)	182.531(SD=21.13)
Trochanter/Shoulder soft tissue ratio	0.994(SD=0.1)	0.835(SD=0.06)
ASIS/Shoulder soft tissue ratio	0.942(SD=0.12)	0.799(SD=0.1)

(p<0.001)

22% of the cases. The authors stated that this might have been due to intraoperative and postoperative pelvic orientation differences. Similarly, Hill et al. [17] presented the comparison of the hip inclination angled between the intraoperative photographs and postoperative radiographs and showed that the inclination angles measured intraoperatively were 13^0 less than those obtained from the postoperative radiographs. In another article published by Otero et al. [18], the preoperative standing pelvic anteroposterior radiographs and intraoperative lateral decubitus pelvis anteroposterior radiographs of 248 hip arthroplasty patients were compared. The authors reported a difference of more than 10^0 between the acetabular inclination angles in the radiographs taken in the standing and lateral decubitus positions in approximately 20% of the patients. This difference exceeded 20^0 in around 3%. In an earlier study, undertaken Han et al. [19] compared the pelvic AP radiographs in the standing and lateral decubitus positions in men and women. They showed that the pelvic inclination was less in the male group with a high shoulder/pelvis ratio than the females according to lateral decubitus radiography. Our study investigated the relationship between shoulder/pelvis bone and soft tissue ratios. According to our results, a higher shoulder/pelvis soft tissue ratio is significantly correlated with the postoperative acetabular cup inclination angle. It was more pronounced in female patients in our sample. Many navigation systems have been defined to minimize the margin of error in manual techniques in determining acetabular orientation angles in THA. Some of these systems are based on reference points on the patient's body, while others prefer to the horizontal plane [12,13]. Skyes et al. [20] applied the alignment determination systems to pelvis models and patients and stated that when the system was applied to patients, there was a deviation of more than 5^0 in inclination in approximately 75% of the cases. The authors suggested that the navigation systems used in hip arthroplasty should also be based on some landmarks to be determined on the patient's pelvis. Meermans et al. [14] described using a digital inclinometer based on the horizontal plane, which resulted in an average inclination error of 12.3^0. The authors also noted that this margin of error was proportional to the hip circumference. Peters et al. [10] used smartphone technology to determine inclination angles by taking the horizontal plane rather than determining reference points on the patients. They stated that although the inclination angles were consistent with the preoperative and postoperative radiographs, the preoperative and postoperative angles were precisely the same for only 42% of the patients. There were slight differences between the intraoperative and postoperative measurements for the remaining patients. In the navigation system described by Kanoh et al. [12], Schanz pins placed in both ASIS points of the patients were taken as reference. This resulted in the successful placement of the acetabular cup at appropriate angles. Similarly, the robotic-assisted navigation system used by Domb et al. [13] reduced the margin of error in patient positioning by taking the patient's acetabulum and femur as reference points and achieved 100% success according to Lewinnek's safe zones. As can be seen in the literature, although attempts have been made to standardize acetabular inclination angles with different navigation systems, the error rate for navigation systems based on the horizontal plane is higher than for navigation systems based on some reference points on the patient's body. We standardized all cases in our study with a horizontal plane-based spirit level assisted navigation system. We think the error rate we encountered in the postoperative inclination values is due to the influence of soft tissue width in the hip region on pelvic orientation in the lateral decubitus position. Direct roentgenography is commonly used in orthopedic practice to visualize bony lesions. Although soft tissue roentgenography seems to have given its place to advanced investigations such as MRI, it is still used in cases such as detecting occult bone pathology and the early diagnosis of soft tissue tumors and infections. In assessing direct radiographs, the mere focus on bone tissue may cause various soft tissue conditions to go unnoticed. In our study, we measured and proportioned the soft tissue thicknesses in the pelvic and shoulder regions in the lateral decubitus position that we believe impact the patient's pelvic orientation, such as the trochanter, ASIS, and shoulder. Because these radiographs were routine radiographs of the pelvis AP and chest obtained as part of the preoperative planning and preparation for surgery, no additional procedure was required, and no extra costs were incurred. The ease of procurement and applicability of the material used are also other advantages. The importance of our study is that the postoperative inclination angle had a strong negative correlation with the trochanter/shoulder soft tissue ratio, moderate negative correlation with the ASIS/shoulder soft tissue ratio, and a weak negative correlation with the trochanter/shoulder bone and ASIS/shoulder bone ratios. Furthermore, the postoperative inclination values were significantly lower in patients with high soft-tissue thicknesses in the hip region. We think that in the lateral decubitus position, the increase in the hip's width compared to the width in the shoulder causes the craniocaudal tilt on the patient's pelvis compared to the normal position. For this reason, we think that in patients with wide hips, we get lower angles than the targeted acetabular inclination angles based on the horizontal plane. It may be beneficial to support the patient during positioning with pillows to be placed in the shoulder area, increase the angle of inclination during acetabular implantation, or check the angle of inclination with fluoroscopy, especially in patients with high soft tissue thickness around the hip.

Limitations of study

The retrospective design of our study is a significant limitation. Another limitation is that we did not calculate the system's error rate based on the horizontal plane. Still, we placed a water gauge on the operating table and controlled the parallelism of the table by the floor to limit the error rate for all cases. Today, direct radiographs are used to visualize bone tissue and are developed in this direction. To visualize soft tissue on plain radiographs, dose adjustment may be required. However, it is often possible to make this adjustment in PACS systems. In conventional imaging, where no dose adjustment can be made, the measurement may not be made over soft tissue shadows. Also, soft tissue shadows in morbidly obese patients do not always fit within the imaging area. These factors may prevent measurement and standardization. In cases that may cause leg length inequality and lumbosacral arthrosis, such as scoliosis and ankylosing spondylitis, the position of the pelvis in the lateral decubitus position may change for each patient in the presence of built-in pelvic tilt and pelvic obliquity, in such cases, the importance of the hip/shoulder ratios may decrease. In addition, the small size of our sample is a limitation of our study. Studies with more patients will certainly be more enlightening in terms of the Trochanter/shoulder ratio effect on postoperative inclination angle.

Conclusions

Our study demonstrated the effects of patients' shoulder and hip bone and soft tissue widths on their postoperative acetabular inclination angles after standardizing this angle during surgery with a horizontal plane-based navigation system. In hip arthroplasty, soft tissue thickness in the patient's shoulder and hip region affects the patient's pelvic orientation in the lateral decubitus position, which influences postoperative acetabular cup inclination. As the hip/shoulder width ratio increases, the patient's posture in the lateral decubitus position changes, and the acetabular inclination angle indirectly decrease when a standardized method of cup application is used. This suggests that the expected inclination angle may be lower than the target value when the acetabular cup is implanted in patients with large hip width on the preoperative radiographs using standard methods. However, the opposite is also true. For the same reason, the expected postoperative acetabular tilt inclination angle will be low in patients with a low hip/shoulder width ratio. Knowing the relationship between the patient's preoperative hip and shoulder distance can influence the expected clinical outcome after hip arthroplasty. Therefore, surgeons should consider these effects when planning hip arthroplasty surgery.

Ethical declarations

Ethics committee approval

The study was carried out with the permission of Gaziosmanpaşa Training and Research Hospital Clinical Research Ethics Committee (Date: 23.09.2020, Decision No: 130).

Informed consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee evaluation process

Externally peer-reviewed.

Conflict of interest statement

The authors have no conflicts of interest to declare.

Financial disclosure

The authors declared that this study has received no financial support.

Author contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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