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The anatomical characteristics of Vietnamese adult hip joint: a multiplanar reconstruction computer tomographic study

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SUMMARY

Background. The present study evaluated some anatomical characteristics of the acetabulum and proximal femur in the hips of adult asymptomatic Vietnamese individuals.
Methods. We used 32 slice computed tomographic system with a multiplanar reconstruction (MPR CT) protocol to evaluate several parameters of the acetabulum and proximal femur, including Acetabular diameter (ADi), Acetabular depth (ADe), Acetabular ratio (AR, calculated by (ADe/ADi) x100), Acetabular inclination angle (AI), Acetabular anteversion angle (AA), Centre-edge angle (CE), Femoral head diameter (FDi), Femoral neck anteversion (FA), Combine anteversion angle (CA, calculated by AA + FA), Femoral shaft-neck angle (SN), and Femoral medial offset (FO). **Results.** The average of parameters of ADi, ADe, AR, AI, AA, CE, FDi, FA, CA, SN, FO were 50.0 ± 2.9 mm; 24.3 ± 2.2 mm; 48.5 ± 3.7 mm; 38.5 ± 3.9°; 17.2 ± 7°; 38.3 ± 6.4°; 44.4 ± 2.9 mm; 13.7 ± 10.4°; 30.8 ± 13.2°; 129.5 ± 5.8°; 32 ± 4.9 mm, respectively. There were no significant differences between the sexes in ADi ($P < 0.001$), ADe ($P < 0.05$), FDi ($P < 0.001$). Males had significantly larger acetabula and femoral heads. There was evidence of a statistically significant negative association between age and ADi, FDi, SN ($P < 0.05$). There was evidence of a statistically significant positive association between ADi and ADe ($P < 0.001$), ADi and FDi ($P < 0.001$), AI and CE ($P < 0.05$), SN and FO ($P < 0.001$). **Conclusion.** There are marked quantitative differences between hip joint parameters of healthy adult Vietnamese individuals and what is reported in other ethnic groups. These data constitute a baseline for future research related to hip joint pathology and hip joint replacement surgery in Vietnamese subjects.

KEY WORDS
hip joint; anatomy; morphology; Vietnamese subjects; hip joint arthroplasty

INTRODUCTION

The various anatomical components of the hip joint work together in a complex mechanical arrangement, allowing the hip to function in the three dimensions. A full understanding of these parameters and how they interact with each other is a key factor for successful hip arthroplasty surgery.

The development of multislice computed tomographic system (CT) with multiplanar reconstruction (MPR) and computer graphic software allows to precisely evaluate the morphology and dimensions of the acetabulum and the proximal femur. Multiplanar reconstruction CT allows to build accurate models taking into account the shape, size and motion of the hip joints in three-dimensional space, so as to predict what will occur when performing hip arthroplasty surgery. The present study evaluates some characteristics of shape, size, and orientation in space of the hip joint of Vietnamese adults using MPR CT.

MATERIALS AND METHODS

Study design and data source

Using a cross-sectional study design, 41 patients were selected from our records. Patients had been seen in the clinic with a unilateral hip lesion, ranging from femoral neck fractures, avascular necrosis of the femoral head, or primary osteoarthritis. All patients lived in Hanoi, were skeletally mature (> 20 years old), with no structural abnormality of the spine and pelvis, and had no previous hip surgery. We collected information about age, gender, height (meter), body mass (kilogram), body mass index (BMI = W/H^2), diagnosis of the condition they suffered from, the affected side from medical records. The study received full ethics approval from the local ethics committee of Saint Paul University Hospital, Hanoi, Vietnam, and follows the criteria and guidelines of Muscles Ligaments and Tendons Journal (1,2).

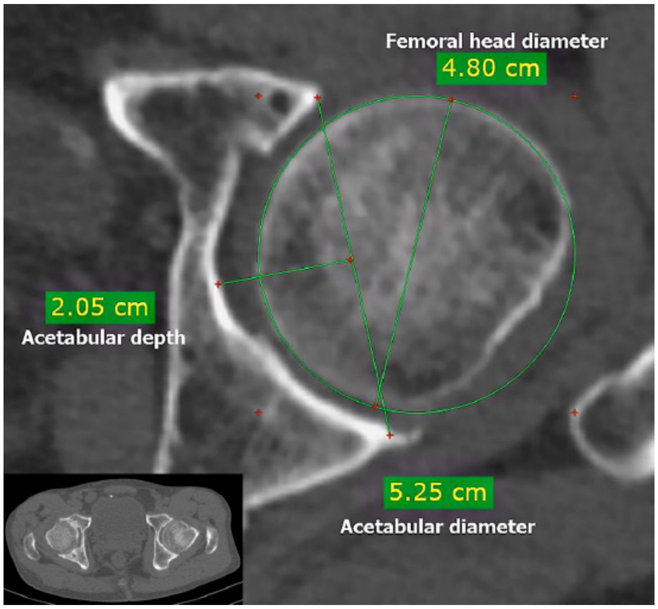

Figure 1. The Acetabular diameter (ADi), Acetabular depth (ADe) and Femoral head diameter (FDi) in the axial plane

Measurement Performance and Methods

We used the Siemens SOMATOM perspective 32 slices, Siemens Healthcare GmbH, Germany CT scanner. The patient was placed supine, balanced on the plane of the table so that the superior anterior iliac spines were at the same level. The lower limbs were fully extended, and internally rotated of 10 - 15°. The measurement used a 5 mm slice thickness, 0.75 mm reconstruction, a 0.7 to 1.3 mm interval between each slice. The process started from the top of the pelvis to below the tibial tubercle. The beam intensity was 80-120 mA, with a total dose of 247 mGy*cm. The axial plane (AP) was defined as the vertical plane passing through the superior-anterior iliac spines, perpendicular to the axis of the body. The coronal plane (CP) was defined as the plane parallel to the body axis and the axial plane.

On MPR windows, a circle was designed to cover the femoral head, identifying the transverse section of the AP and CP, at which point the size of the acetabulum and the femoral head are the largest. On the AP, the acetabular diameter (ADi) was defined as the distance between the outermost points of the anterior and posterior collum of the acetabulum, in millimeters (**Figure 1**). Acetabular depth (ADe) was defined as the distance from the midpoint of the ADi line to the innermost point of the acetabulum, measured in millimeters (**Figure 1**). Also in this plane, based on the circle previously drawn, the femoral head diameter (FDi) was determined, in millimeters (**Figure 1**). The acetabular ratio (AR) was calculated using the formula AR = (ADe / ADi) x 100.

On the AP, the line connecting the posterior end of the ischial tuberosities was defined as the inter-ischial-tuberosity line. The acetabular anteversion angle (AA) was defined as the angle formed by the ADi line and the line perpendicular to the inter-ischial-tuberosity line, measured in degrees (**Figure 2**).

The inter-ischial-tuberosity line was identified on the CP or scout view windows. The acetabular inclination angle (AI) was defined as the angle formed by a line tangent to the lowed edge of the teardrop connecting with the outermost superior margin of the acetabulum and the inter-ischial-tuberosity line, measured in degrees. The acetabular centre-edge angle (CE) was defined as the angle formed by the line connecting the centre of the femoral head and the outermost superior margin of the acetabulum, with the line through the centre of the femoral head and perpendicular to the inter-ischial-tuberosity line, measured in degrees (**Figure 3**).

Using the CT overlapping technique, we identified the femoral neck anteversion angle (FA)(3). The femoral neck axis was defined as the line passing through the midpoints of the neck at the most proximal portion of the inferior aspect of the neck, on a CT slice when the head was not visible. The posterior condylar axis was defined as the line drawn along the largest femoral condyle on the CT slice. A line drawing of both proximal and distal slices was produced on two separate sheets of paper. The

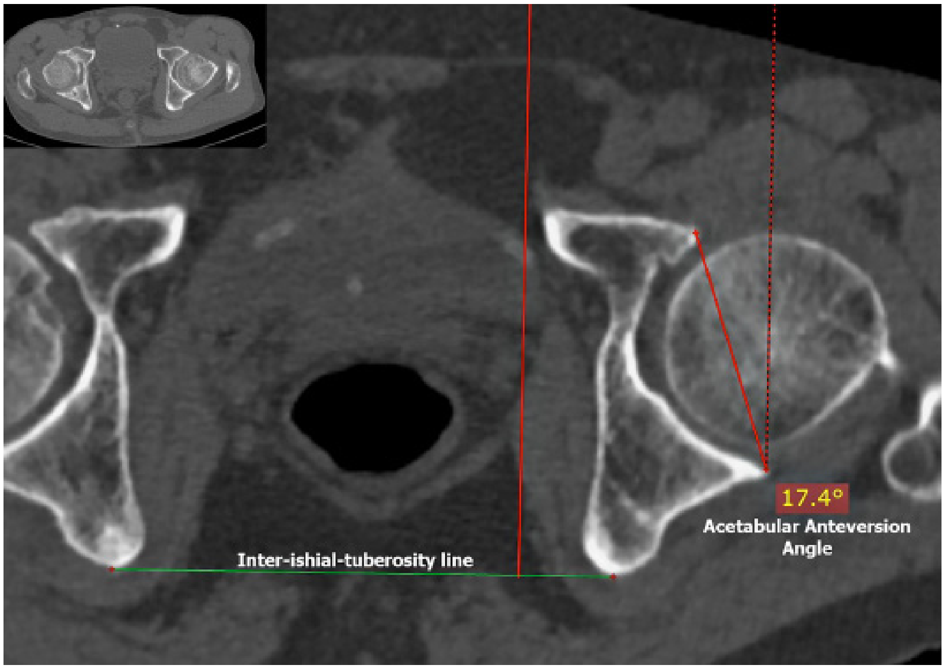

Figure 2. The Acetabular Anteversion (AA) in the axial plane

two sheets were overlapped on the same plane, and the femoral anteversion was calculated by reading the angle between the femoral neck axis and the posterior condylar axis (**Figure 4**). The acetabular combined anteversion angle (CA) was calculated using the formula CA = AA + FA, measured in degrees.

On the CP, the line passing through the centre of the femoral head and the midpoint of the superior and inferior border of neck medullary canal determined the femoral neck axis. The line passing through two midpoints of the outer and inner medullary canal in the proximal one third of the femur defined the femoral shaft axis. The

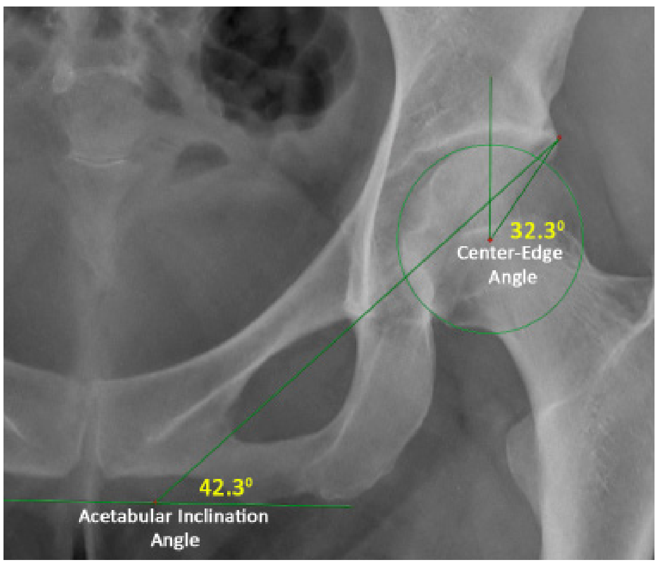

Figure 3. The Acetabular Inclination (AI) and Centre-Edge (CE) Angle in a scoutview window

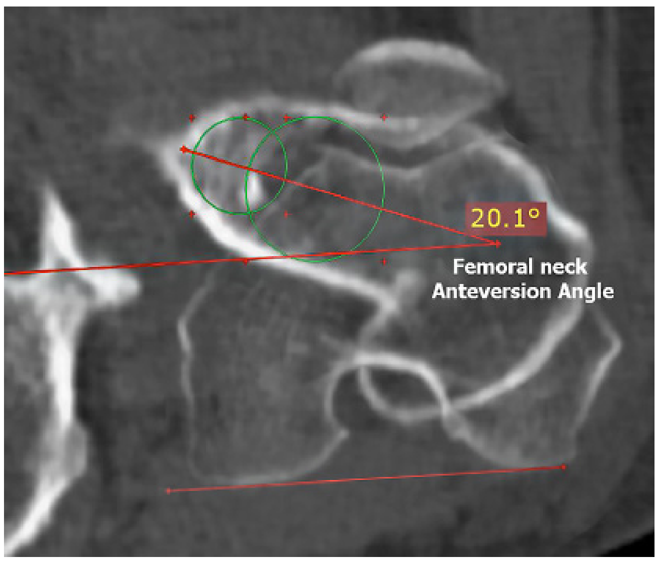

Figure 4. The Femoral neck anteversion angle (FA) in computed tomographic (CT) overlapped axial plane

femoral shaft-neck angle (SN) was defined as the angle between the femoral neck axis and the femoral shaft axis, measured in degrees (**Figure 5**). The medial femoral offset (FO) was defined as the distance from the centre of the femoral head to the femoral shaft axis, measured in millimeters (**Figure 5**).

Statistical Analysis

The data were measured independently by two authors (D.TT and H.PT), and the mean of the results were statistically analyzed. All data were expressed as means ± standard deviation (SD), range and distribution.
Differences were analyzed using SPSS ver. 23.0, IBM, New York statistical software. Patients were divided accord-ing to gender and hip side. Analysis of variance was used to determine significant differences ($P < 0.05$) between the two groups. The F-test was used to investigate the state of dispersion. The Student t-test was used to determine signif-icant differences.
One-way ANOVA was used to analyzing the difference between mean values of the various parameters between the age and diagnostic groups. The association between the mean values of the parameters age and BMI, was tested using the bivariate association test, using Pearson correlation coefficients for standard deviation, with two-tailed significance. With quantitative variables having the same measurement units and determined to be associated, we used linear regression test to find the correlation formula, with a confidence interval of 95%.

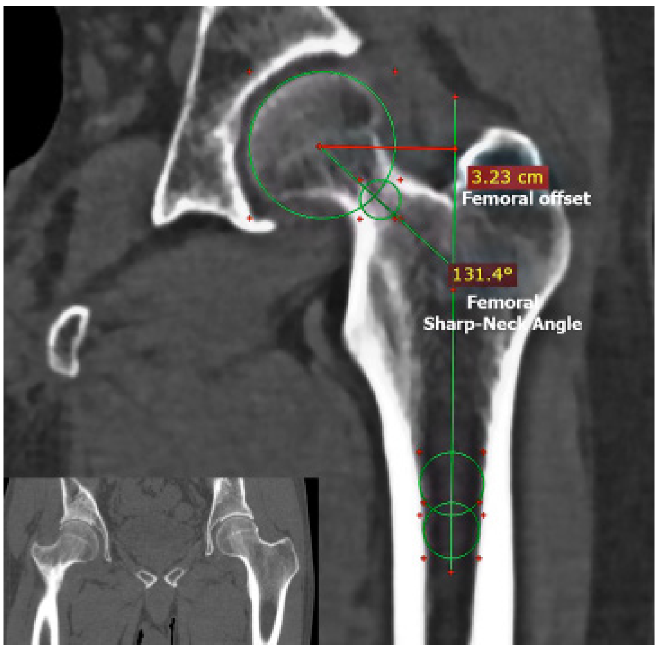

Figure 5. The Femoral shaft-neck (SN) angle and Femoral offset (FO) in the coronal plane

RESULTS

A total of 41 subjects (26 males and 15 females; average age; 62.12 ± 14.76 years, range 20 to 91 years; mean body mass index 21.31 ± 1.89, range 17.58 to 27.94; 13 right hips and 28 left hips) were included in the present investigation. The proportion of subjects with trauma, osteonecrosis, and osteoarthritis was 21 (51.2%), 12 (29.3%) and 8 (19.5%), respectively.
The morphologic parameters of the acetabulum and femur are reported in **Tables Ia** and **Ib.**
The one-way ANOVA and the Student T-test showed no significant differences between the mean of the parameters among the age groups, the diagnosis groups, and the hip side groups. **Table IIa** and **Table IIb** show the average of the various parameters in males and females. There were significant differences in acetabular diameter, acetabular depth and femoral head diameter between the sexes ($P < 0.001$, 0.002 and <0.001, respectively). The indexes for males were significantly higher, on average, than for females.

Table Ia. Anatomical parameters of the acetabulum in Vietnamese adults

	A.Di	A.De	A.R	A.I	A.A	C.E
Mean	50.0	24.3	48.5	38.5	17.2	38.3
Standard Deviation	2.9	2.2	3.7	3.9	7.0	6.4
Minimum	45.0	20.6	41.2	31.2	3.6	18.2
Maximum	56.3	30.0	58.8	47.1	31.2	50.7

Table Ib. Anatomical parameters of the proximal of femur in Vietnamese adults

	F.Di	F.A	C.A	S.N	F.O
Mean	44.4	13.7	30.8	129.5	32.0
Standard Deviation	2.9	10.4	13.2	5.8	4.9
Minimum	38.9	- 6.2	6.9	116.0	24.5
Maximum	49.0	41.0	68.3	142.0	45.0

List of the abbreviations to Table Ia and Ib: A.Di – Acetabular diameter; A.De – Acetabular depth; A.R – Acetabular ratio; A.I – Acetabular inclination angle; A.A – Acetabular anteversion angle; C.E – Centre-edge angle; F.Di – Femoral head diameter; F.A – Femoral neck anteversion; C.A – Combine anteversion angle; S.N – Femoral shaft-neck angle; F.O – Femoral medial offset.

Table IIa. Sex-based analysis in parameters of the acetabulum in Vietnamese adult

	Gender	Mean	Std. Deviation	P
Acetabular Diameter	Male	51.5	2,4	**< 0.001**
	Female	47.5	1.6	
Acetabular Depth	Male	25.0	2.2	**0.002**
	Female	22.9	1.4	
Acetabular Inclination	Male	38.6	3.8	0.825
	Female	38.3	4.3	
Acetabular Anteversion	Male	16.3	7.1	0.302
	Female	18.7	6.8	
Centre-Edge Angle	Male	38.2	6.4	0.897
	Female	38.5	6.6	
Acetabular Ratio	Male	48.7	4.3	0.713
	Female	48.2	2.4	

Table IIb. Sex-based analysis in parameters of the proximal of femur in Vietnamese adult

	Gender	Mean	Std. Deviation	P
Femoral head diameter	Male	45.9	2.3	**< 0.001**
	Female	41.8	1.7	
Shaft Neck Angle	Male	130.7	6.0	0.093
	Female	127.5	49	
Femoral neck Anteversion	Male	13.3	11.7	0.749
	Female	14.3	7.8	
Femoral offset	Male	32.5	5.5	0.419
	Female	31.3	3.6	
Combine Anteversion Angle	Male	29.6	14.8	0.423
	Female	33.0	9.8	

The bivariate correlations test showed no evidence of a statistically significant association between the various parameters and BMI. **Table 3** shown the association between parameters and age of patients, with evidence of a statistically significant negative association between acetabular diameter, femoral head diameter, femoral neck-shaft angle with age, with the correlation Pearson value was -0.37; -0.34; -0.35 and the P value was 0.016; 0.03; 0.027, respectively.

Table III. Age-based analysis in parameters of hip joint in Vietnamese adult

Parameter	Pearson	P	Parameter	Pearson	P
A.Di	- 0.37*	**0.016**	F.Di	- 0.34*	**0.030**
A.De	- 0.29	0.06	F.A	0.27	0.090
A.R	- 0.08	0.625	C.A	0.24	0.059
A.I	- 0.23	0.143	S.N	-0.35*	**0.027**
A.A	0.24	0.125	F.O	- 0.09	0.586
C.E	0.09	0.540			

*: Significant at the 0.05 level (2-tailed).

List of the abbreviations to Table III: A.Di – Acetabular diameter; A.De – Acetabular depth; A.R – Acetabular ratio; A.I – Acetabular inclination angle; A.A – Acetabular anteversion angle; C.E – Centre-edge angle; F.Di – Femoral head diameter; F.A – Femoral neck anteversion; C.A – Combine anteversion angle; S.N – Femoral shaft-neck angle; F.O – Femoral medial offset.

Regarding the relationship between sizes, ADi has a positive correlation with Ade, with the correlation linear equation being A.De = A. Di x 0.4 + 3.9 mm. Similarly, ADi had significant positive correlation with FDi with correlation equation was A. Di = F. Di x 0.9 + 10.9 mm, with the linear equation being A.De = F. Di x 0.4 + 14.3 mm.

When comparing the mean of the various parameters, the bivariate correlations test and linear regression analysis showed evidence of statistically significant association between acetabular and femoral head sizes and angles of acetabular and proximal femoral. In details, there was evidence of a statistically significant positive association between Acetabular Diameter and Depth (R: 0.53, $P < 0.01$; linear equation: A.De = A.Di x 0.4 + 3.9 mm). There was a positive association between Acetabular diameter and Femoral head diameter (R: 0.89, $P < 0.001$; linear equation was: A.Di = F.Di x 0.9 + 10.9 mm). There was a positive association between Acetabular inclination angle and Centre – Edge angle (R: 0.37, P = 0.009; linear equation: C.E = 61.2 – A.I x 0.6 degree). There was a positive association between Acetabular depth angle and Centre – Edge angle (correlation Pearson value: 0.42, P = 0.006). There was evidence of a statistically significant negative association between Femoral shaft-neck angle and Femoral offset (correlation Pearson value: - 0.59, $P < 0.001$).

DISCUSSION

The average acetabular diameter in our Vietnamese subjects was 50 ± 2.9 mm, and the average of acetabular depth was 24.3 ± 2.2 mm. When compared with the investigation by Zeng et al. in 100 Chinese hip joints, their mean of acetabular diameter was greater than in our Vietnamese subjects, with 56 mm in males and 51.4 mm in females, although the acetabular depth was more shallow with 19.4 mm in males and 17.4 mm in females (4). The mean acetabular depth in the present study was similar to that reported in 266 Malaysian hip joints with 25.6 mm (5). The average femoral head diameter in Vietnamese subjects was 44.4 ± 2.9 mm, similar to what reported by Nakahara et al. in 136 Japanese hip joints at 44.9 mm (6). Although there was no association with BMI, the size of acetabular and femoral head of Vietnamese individuals was similar to those of other Asian ethnic groups.

Comparative analysis of data on the shape and orientation of the acetabulum in Vietnamese (**Table Ia**) and in other Asian ethnic groups (**Table IV**) revealed that the average of acetabular ratio (depth/diameter) in Vietnamese (48.5 ± 3.7%) was higher than in Chinese subjects (34.7% in male and 33.9% in female) (4). The average of AI (38.5 ± 3.9°) was similar to the mean of Chinese, Malaysian and Japanese people's (39.5°, 38.14° and 38.2 respectively) (4-6). The average of AA (17.2 ± 7°, with the wide range from 3.6° - 31.2°) was smaller than the mean of other Asian ethnic groups. (Malaysian – 19.96°, Japanese – 20.2°, Indian – 19°, Chinese – 18.79°) (5-8). The average CE (38.3 ± 6.4°) was greater than mean the of Chinese population (33.3° in male and 32.8° in female) (8) and Japanese population (35.8°) (6). The CE had a significant positive correlation with AI and AA. From the above data, it was possible to ascertain that the Vietnamese acetabular shape tended to be more hemispherical, with AR close to 50%. At the same time, given the large CE, the coverage of the acetabulum was also greater.

The average SN in Vietnamese (129.5 ± 5.8°), was lower than the value of Caucasian (137.43°) (9) and of Chinese (133.02°) (8) subjects, but was greater than the mean of Japa-

Table IV. Shape and orientation of the acetabulum in Vietnamese and other Asian ethnic groups.

Population	Acetabular Ratio (AR)	Acetabular Inclination (AI)	Acetabular Anteversion (AA)	Centre-Edge Angle (CE)	Femoral shaft-neck angle (SN)	Femoral neck anteversion (FA)
Vietnamese (current study)	48.5 ± 3.7%	38.5° ± 3.9°	17.2° ± 7° (range 3.6° - 31.2°)	38.3° ± 6.4°	129.5° ± 5.8°	13.7° ± 10.4° (range 6.2°–41.00)
Chinese (AR and AI[4]; AA, CE, SN and FA[8])	34.7% in male, 33.9% in female	39.5°	18.79°	33.3° in male, 32.8° in female	133.02°	10,62°
Japanese[6]	–	38.2±4.1	20.2°	35.8° ±6.0°	125.1°	22.4°
Malaysian[5]	–	38.14°	19.96°	–	–	–
Indian[7]	–	–	19°	–	–	8°
Caucasian[9]	–	–	17.20° in male, 22.59° in female	–	137.43°	–

nese subjects (125.1°) (6). The average of FO in Vietnamese subjects was 32 ± 4.9 mm, with evidence of a statistically significant negative association between SN and FO. SN and FO have an important role in balancing the moment arm of the hip: the change in SN and FO values after hip replacement surgery can directly affect the gait of the patient and the weight bearing function of the prosthetic hip. Applied to the conditions in Vietnam, most of the manufacturer's use the stem type with SN was 135°. Hence, after hip arthroplasty, this will exert a direct impact on the weight bearing system of the hip. Therefore, it may well be necessary to undertake specific studies to design hip arthroplasty devices more appropriate to the anatomical characteristics of Vietnamese people.

The average FA and CA in Vietnamese were 13.7 ± 10.4° (range from 6.2° to 41.0°) and 30.8 ± 13.2° (range from 6.9° to 68.3°). Compared with other studies, the FA of Vietnamese subjects was higher than that of Indian (8°) (7) and Chinese (10,62°) (8), but lower than the value of Japanese subjects (22.4°)[6]. The combine angle anteversion is the sum of AA and FA: this angle represents the relative motion between acetabulum and femoral head. Several authors have proposed equations to use CA as a criterion for orientation of prosthetic components to avoid dislocation and impingement. Widmer et al recommended that the CA should be 37.3° (10); Dorr et al suggested that it should be 37.6 ± 7° (11); Nakashima et al. recommend a CA of 40-60° (12). In our study, although both CA and FA had high variability, the average of them were still in the same range as the other studies. Thus, in hip replacement surgery, anatomical parameters of the hip could be used to determine the optimal location of the hip joint components. However, to confirm this, more research about the combine anteversion angle is needed.

Tables IIa and **IIb** show that the average of the diameter and the depth of acetabulum in males were significantly greater than the average in females (51.5 ± 2.4 mm versus 47.5 ± 1.6 mm, P <0.001, and 25.0 ± 2.2 mm versus 22.9 ± 1.4 mm, P = 0.002, respectively). Similarly, the average of femoral head diameter in males was higher than in females (45.9 ± 2.3 mm versus 41.8 ± 1.7 mm, P < 0.001). However, according to our data, the average acetabular anteversion angle in Vietnamese males was lower than that of females (16.3° versus 18.7°), similar to what found in other studies (4, 6, 8-9) (**Table V**). There was no significant difference between the sexes in other variables.

The equations developed can be applied to templating for hip arthroplasty surgery, based on the femoral head diameter measured on plain radiographs or directly during the procedure, so as to estimate the diameter and depth of acetabulum used during surgery.

We acknowledge that our study has limitations. For example, we are aware that the sample studies is relatively small, and thus may not be representative of the entire Vietnamese population. In addition, the study was performed on patients with unilateral hip ailments, and we did not perform a comparison with a healthy population. However, our ethics committee did not allow us to use radiography in asymptomatic individuals for the sole purpose of measuring the variables studies in the present investigation. Finally, the imaging assessment undertaken in the present study does not allow to produce an accurate evaluation in the three dimensions.

The present investigation evidences statistically significant negative association between patient's age and ADi, FDi and SN, respectively, one can assume that the higher the age of the patient, the lower the bone quality and the consequent bone loss, resulting in the reduction of the diameter of the acetabulum and the femoral head. At the same time, weight bearing of the femoral neck was reduced, thereby lowering the SN. However, this assumption needs empirical support.

CONCLUSION

The dimensional variables of normal hip joints in Vietnamese adults were similar to those described in other Asian populations, but the acetabular shape was more hemispherical and covered a larger area when compared to Japanese and Chinese subjects. The femoral shaft-neck angle is lower, but the medial offset and the combined anteversion angle were not higher. These values were within the limits reported in other studies. The peculiarity of the anatomi-

Table V. Acetabular anteversion angles in Vietnamese and other ethnic groups by sex

Gender	Average acetabular anteversion angle					
	Vietnamese (current study)	Chinese (Zeng, 2012)	Chinese (Jiang, 2015)	Japanese (Nakahara, 2011)	Caucasian (Atkinson, 2010)	USA (Maruyama, 2001)
Male	16.3°	16.0°	18.27°	17.8°	17.2°	18.15°
Female	18.7°	17.6°	20.44°	23°	22.59°	21.3°

cal characteristics described could be used to determine the orientation of the prosthetic component during total hip arthroplasty surgery in Vietnamese subjects.

Conflict of Interest

The authors declare that they have no conflict of interest

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