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Original Article

Anatomy Section

Acetabular Parameters in Adults and their Clinical Implications: A Cross-sectional Study

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ABSTRACT

Introduction: The hip bones comprise the ilium, ischium and pubis. The acetabulum is a bony part of the hip bone derived from the convergence of the ilium superiorly, the ischium posteriorly, and the pubis anteriorly. The dimensions of the acetabulum are significant in the orthopaedic evaluation and treatment of acetabular dysplasia (hip dysplasia), Osteoarthritis (OA) of the hip joint, pincer type of impingement, acetabular fractures, congenital and acquired dislocation of the hip joint and hip arthroplasty. The clinical and anthropological importance of acetabular morphometry was considered the main background for conducting the present study.

Aim: To assess the morphometry and morphology of the acetabulum in the study population and compare the gender and side differences.

Materials and Methods: The present cross-sectional study was conducted in the Department of Anatomy, PSG IMSR, Coimbatore, western part of Tamil Nadu, India, from July 2015 to December 2015. One hundred (53 males, 47 females) dry hip bones were procured from the Anatomy Department. Morphological and morphometric parameters of the acetabulum, such as diameter, depth, capacity and Anterior Acetabular Ridge (AAR), were assessed in males and females for left-side and right-side (divided in eight groups), and then evaluated statistically using Independent t-tests, one-way Analysis of Variance (ANOVA) and Pearson's correlation tests.

Results: Of all 100 hip bones, the mean±Standard Deviation (SD) values of the diameter, depth and capacity were 48.55±3.68 mm, 22.94±2.91 mm and 31.10±11.02 mL, respectively. The curved type of AAR was observed predominantly in 50 (50%) hip bones, while the straight type of AAR was found to be the least common in 13 (13%). The differences in diameter, depth and capacity of the acetabulum between males and females were statistically significant (p-value<0.001).

Conclusion: The acetabular parameters were documented along with their clinical implications. Significant differences were observed between males and females in all parameters. A radiological approach will be the future scope of the present study.

Keywords: Arthroplasty, Impingement, Morphology, Morphometry, Osteoarthritis

INTRODUCTION

Hip bones consist of the ilium, ischium and pubis. The acetabulum is a bony part of the hip bone formed by the convergence of the ilium superiorly, the ischium posteriorly and the pubis anteriorly. It features an anterior ridge, an inferior notch and a horseshoe-shaped lunate articular surface. The acetabulum and the head of the femur articulate to form the hip joint, which is vital both functionally and clinically [1-4]. The ossification of the acetabulum is completed by the ages of 17-18 years [4,5]. The acetabulum is of orthopaedic significance in conditions such as acetabular dysplasia (hip dysplasia), OA of the hip joint, pincer type impingement, acetabular fractures, congenital and acquired dislocation of the hip joint, and hip arthroplasty. It also carries anthropological importance. Developmental dysplasia of the hip can lead to further complications, including dislocation and OA [6-8].

Osteoarthritis is the 20th leading cause of Years Lived with Disability (YLD) in India, with OA of the knee being the most common in the lower limb, followed by OA of the hip. Approximately 63 million people suffered from OA in 2019. The disease-adjusted life years due to OA, as well as, the prevalence and incidence of OA, were higher in females than in males. Early diagnosis and effective treatment of acetabular dysplasia can prevent OA in its early stages and dislocation later in life [9-11]. Femoroacetabular Impingement Syndrome (FAIS) includes a subtype known as pincer impingement, which results from anterior acetabular overcoverage. This underscores the importance of the acetabular morphology in AAR. AAR has been classified into four major types: curved, straight, angular and irregular [12-14].

The morphometry and morphology of the acetabulum enhance our understanding of the etiopathogenesis of anterior and posterior acetabular fracture patterns [15-17]. Two types of hip dislocation, congenital and dysplastic, were observed with a female preponderance [18-20]. Preoperative templating of acetabular morphometric parameters is essential in designing acetabular prostheses for hip arthroplastic procedures [21-23]. The acetabular parameters have been assessed among Indian and other populations in previous studies [24-35]. However, due to the significant impact of different geographical conditions and genetic traits across the subcontinent, as well as, the lack of adequate reports representing the western part of Tamil Nadu, India, the present study was undertaken with the aim of assessing the morphometry and morphology of the acetabulum in the authors study population and comparing gender and side differences.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Anatomy, PSG IMSR, Coimbatore, western part of Tamil Nadu, India, from July 2015 to December 2015. Institutional Human Ethical Committee approval (14/157) was obtained, along with a waiver of consent.

Sample size: A total of one hundred (N=100) dry acetabula were included based on convenience sampling due to resource constraints.

Inclusion criteria: Normal fused hip bones with intact acetabula (including both males and females) were included in the study.

Exclusion criteria: Fractured hip bones were excluded from the study.

Study Procedure

The sex of the hip bones was determined from departmental records. Morphometric parameters, such as diameter, depth and capacity of the acetabulum, were measured and documented for gender (males and females), side (right and left), and for both gender and side combined. The morphology of the acetabulum was observed and documented along with its distribution.

Parameters

1) Diameter of the acetabulum: The transverse acetabular diameter was measured using a digital vernier calliper and the maximum diameter was considered the diameter of the acetabulum [Table/Fig-1] [24].

2) Depth of the acetabulum: The acetabular cavity was examined for its deepest point with the help of a vernier calliper. A metallic scale was placed horizontally over the acetabular brim. The maximum depth was assessed as the distance between the acetabular brim and the deepest point in the acetabular cavity, with the vernier calliper positioned accordingly [Table/Fig-1] [24].

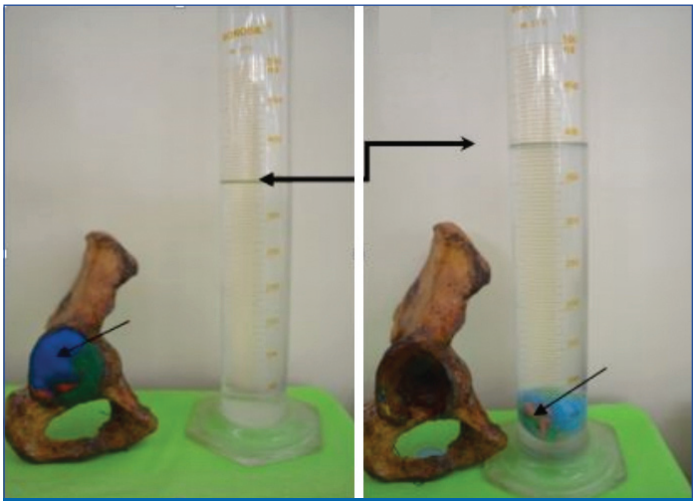
[Table/Fig-1]: Diameter and depth of the acetabulum measured using vernier calliper.

3) Acetabular capacity: Plasticine was used to fill the acetabular cavity. The filling was made up to the brim of the acetabulum. A measuring jar was filled with water, and the initial water level was noted. Then, the mass of the plasticine filled in the acetabulum was dropped into the measuring jar filled with water. The increase in the water level (according to Archimedes' principle) was recorded as the capacity of the acetabulum [Table/Fig-2] [24].

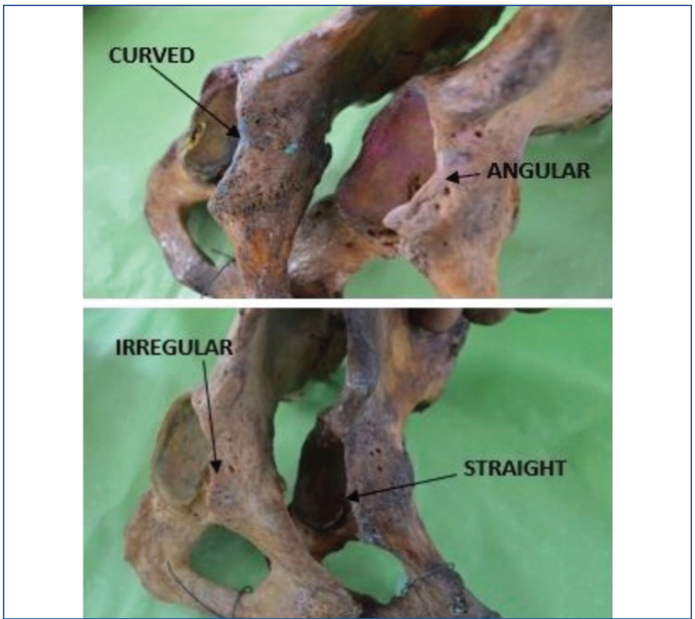
4) Anterior Acetabular Ridge (AAR): The AAR was observed for irregular, curved, straight, or angular types in the samples, and the findings were documented [Table/Fig-3] [25].

STATISTICAL ANALYSIS

Comparisons were made among genders (males and females) and sides (right and left), including both gender and side, with statistical correlations assessed using independent t-tests (unpaired t-tests), one-way ANOVA, and Pearson's correlation tests, all conducted using International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) software version 19.0. A p-value of less than 0.05 was considered significant when comparing the parameters based on gender and sides.



[Table/Fig-2]: Capacity of the acetabulum measured according to Archimedes' principle.



[Table/Fig-3]: Types of AAR.

RESULTS

The mean±SD diameter, depth and capacity for 100 acetabula were 48.55±3.68 mm, 22.94±2.91 mm and 31.10±11.02 mL, respectively. In males (n=53), the mean±SD diameter, depth and capacity were 50.75±2.69 mm, 24.30±2.67 mm and 36.21±11.47 mL, respectively. In females (n=47), the mean±SD diameter, depth and capacity were 46.07±3.02 mm, 21.42±2.39 mm and 25.34±6.98 mL, respectively. For the right-side (n=46), the mean±SD diameter, depth and capacity were 49.07±3.55 mm, 22.58±2.91 mm and 31.28±9.16 mL, respectively. For the left-side (n=54), the mean±SD diameter, depth and capacity were 48.16±3.77 mm, 21.95±3.33 mm and 30.95±12.47 mL, respectively [Table/Fig-4].

Diameter of the acetabulum					
Groups	Minimum (mm)	Maximum (mm)	Mean (mm)	SD (mm)	p-value
Total males (n=53)	44.60	57.51	50.75	2.69	<0.001*
Total females (n=47)	38.22	52.06	46.07	3.02	
Total right (n=46)	41.88	57.51	49.07	3.55	0.256
Total left (n=54)	38.22	56.98	48.16	3.77	
Right males (n=29)	46.16	57.51	50.82	2.76	<0.001*
Right females (n=17)	41.88	50.86	45.91	2.47	
Left males (n=24)	44.60	56.98	50.66	2.66	<0.001*
Left females (n=30)	38.22	52.06	46.16	3.33	

Depth of the acetabulum					
Groups	Minimum (mm)	Maximum (mm)	Mean (mm)	SD (mm)	p-value
Total males (n=53)	19.93	32.73	24.30	2.67	<0.001*
Total females (n=47)	15.95	28.12	21.42	2.39	
Total right (n=46)	15.95	29.03	22.58	2.91	0.635
Total left (n=54)	16.70	32.73	23.26	2.91	
Right males (n=29)	19.93	29.03	23.80	2.58	<0.001*
Right females (n=17)	15.95	24.92	20.50	2.21	
Left males (n=24)	21.67	32.73	24.90	2.71	<0.001*
Left females (n=30)	28.12	16.70	21.95	3.33	
Capacity of the acetabulum					
Groups	Minimum (mL)	Maximum (mL)	Mean (mL)	SD (mL)	p-value
Total males (n=53)	20.00	90.00	36.21	11.47	<0.001*
Total females (n=47)	10.00	45.00	25.34	6.98	
Total right (n=46)	15.00	50.00	31.28	9.16	0.706
Total left (n=54)	10.00	90.00	30.95	12.47	
Right males (n=29)	20.00	50.00	35.16	7.58	<0.001*
Right females (n=17)	15.00	45.00	24.68	7.87	
Left males (n=24)	20.00	90.00	37.49	14.99	<0.001*
Left females (n=30)	10.00	44.25	25.72	6.53	

[Table/Fig-4]: Diameter, depth and capacity of the acetabulum.
*The p-value <0.05 was considered statistically significant

The types of AAR observed in the 100 acetabula were curved (n=50, 50%), straight (n=13, 13%), angular (n=17, 17%), and irregular (n=20, 20%). In both males (n=20/53, 37.8%) and females (n=30/47, 63.8%), the curved type was the most frequently exhibited type of AAR. The least represented types in males were the angular and irregular types of AAR (n=14/53, 26.4%), while in females, the least represented type was the angular type (n=3/47, 6.4%). The most documented type of AAR on both the right-side (n=21/46, 45.7%) and the left-side (n=29/54, 53.7%) was the curved type. The least evidenced type of AAR on the right-side (n=5/46, 10.9%) was the straight type, and on the left-side (n=7/54, 12.9%), it was the irregular type [Table/Fig-5].

Groups	Curved n (%)	Straight n (%)	Angular n (%)	Irregular n (%)
Total males (n=53)	20 (37.7)	05 (9.4)	14 (26.4)	14 (26.4)
Total females (n=47)	30 (63.8)	08 (17)	03 (6.4)	06 (12.8)
Total right (n=46)	21 (45.6)	05 (10.9)	07 (15.2)	13 (28.2)
Total left (n=54)	29 (53.7)	08 (14.8)	10 (18.51)	07 (12.9)
Right males (n=29)	11 (38)	02 (6.9)	06 (20.7)	10 (34.5)
Right females (n=17)	10 (58.8)	03 (17.6)	01 (5.9)	03 (17.6)
Left males (n=24)	09 (37.5)	03 (12.5)	08 (33.3)	04 (16.7)
Left females (n=30)	20 (66.7)	05 (16.7)	02 (6.7)	03 (10)

[Table/Fig-5]: Types of Anterior Acetabular Ridge (AAR).

The mean values of morphometric parameters, such as diameter, depth, and capacity of the acetabulum, when analysed statistically based on gender, showed a significant difference between males and females with a p-value <0.001 (Independent t-test). When analysed based on side, there was a significant difference between the right-side of males and the right-side of females with a p-value <0.001, as well as, between the left-side of males and the left-side of females with a p-value <0.001 ANOVA. When comparing the right-side and left-side (excluding gender), there was statistical insignificance in all the parameters. Based on Pearson's coefficient, all three parameters correlated positively with each other. The 'r' value between diameter and depth was 0.603 (p-value<0.05), between diameter and capacity was 0.589 (p-value<0.01), and between depth and capacity was 0.536 (p-value<0.05).

DISCUSSION

The morphometry of the acetabulum and its congruence with the head of the femur ensure normal biomechanics at the hip joint. The measurements in males were significantly higher than those in females, and the measurements on the right-side were greater than those on the left-side, although this difference was statistically insignificant. The curved type of AAR predominated among the other types.

The anthropometric measurements showed significant differences based on the side of the bone in all three parameters, namely diameter, depth and capacity, as observed in several other studies [24,27-29]. In contrast, the present study found no significant difference based on sides when excluding gender. The comparison of the means of morphometric measurements between males and females was significant, as compared to other studies [24,27-29]. This could be explained by the wide range of population coverage in studies for anthropological documentation. The differences in measurements between the present study and various others can be attributed to the ethnic, genetic and geographical distribution of the study population.

Studies from other countries, such as that by Indurjeeth K, (N=100) in the South African population and Ghafoor A et al., (N=160) in the Lahore population, showed the diameters of the acetabulum to be greater than those reported in the present study [26,27]. The intra and inter-country comparisons of acetabular depth indicated that the acetabula in the present study population were shallower, which could lead to an increased risk of dislocation during trauma. The capacity of the acetabula in males from the present study population was greater than that reported by Ghafoor A et al., (N=160) in the Lahore population, which was the only parameter showing a difference based on gender and adds to the anthropological significance [27]. The shallowness established in females, when compared with the measurements in males, suggests that acetabular dysplasia is common in females based on their bony architecture. However, this does not necessarily indicate a dysplastic nature in females because, when observed through Pearson's correlation, the diameter, depth and capacity positively correlated with each other, establishing stable anatomy. The female preponderance of dysplasia and the further complication of OA might be attributed to the hormonal balance between oestrogen and progesterone during the perimenopausal and postmenopausal stages, leading to the laxity of soft tissues (specifically the ligaments) [36].

The mean value of the acetabular diameter was found to be higher for both genders and on both sides when compared with the observations of Soman MA et al., (N=200) and Pullanna B et al., (N=100) in the Mangaluru population [24,25]. It was found to be lower for both genders and on both sides when compared with the observations of Indurjeeth K (N=100) in the South African population and Ghafoor A et al., (N=160) in the Lahore population [26,27]. The mean value of the acetabular diameter was found to be lower on both sides when compared with the observations of Rajilarajendran HS et al., (N=71) in the Chennai population and Dhindsa GS (N=50) in the Punjab population [28,29]. The mean value of the acetabular diameter on the right-side was higher, while the left-side was found to be lower when compared with the observations of Arunkumar KR et al., (N=104) in the Perambalur population, Tamil nadu, Tripathi M and Gajbhiye V, (N=200) in the Bhopal population, and Vyas K et al., (N=152) in the Baroda population, Gujarat [Table/Fig-6] [24-32].

The mean value of the acetabular depth was found to be lower for both genders and on both sides in this study population when compared with the observations of Soman MA et al., (N=200), Pullanna B et al., (N=100) in the Mangaluru population, Indurjeeth K et al., (N=100) in the South African population, Ghafoor A et al., (N=160) in the Lahore population, Dhindsa GS (N=50) in the Punjab population, Arunkumar KR et al., (N=104) in the Perambalur population, Tripathi M and Gajbhiye V, (N=200) in the Bhopal population, and Vyas K et al., (N=152) in the Baroda population [24-32]. The mean value of the acetabular depth on the right-

Authors	Place and year of study	Parameters	Total males	Total females	Total right	Total left	Right males	Left males	Right females	Left females
Present study	Coimbatore, India, 2015	Diameter (mm) Depth (mm) Capacity (mL)	50.75 24.30 36.21	46.07 21.42 25.34	49.07 22.58 31.28	48.16 23.26 30.95	50.82 23.80 35.16	50.66 24.90 37.49	45.91 20.50 24.68	46.16 21.95 25.72
Soman MA et al., [24]	Mangaluru, India, 2023	Diameter (mm) Depth (mm) Capacity (mL)	48.75 25.41 22.04	45.70 24.45 23.40	47.14 25.41 22.04	47.70 25.71 23.96	48.57 26.14 24.26	48.94 26.63 25.77	45.71 24.69 19.83	45.69 24.22 21.03
Ghafoor A et al., [27]	Pakistan, 2023	Diameter (mm) Depth (mm) Capacity (mL)	52.40 28.10 31.61	46.30 26.10 28.47	52.30 28.10 31.61	53.90 28.00 30.96	NA	NA	NA	NA
Rajilarajendran HS et al., [28]	Chennai, India, 2024	Diameter (mm) Depth (mm) Capacity (mL)	NA	NA	49.33 23.28 27.22	48.57 22.50 27.22	NA	NA	NA	NA
Dhindsa GS [29]	Punjab, India, 2013	Diameter (mm) Depth (mm) Capacity (mL)	NA	NA	51.30 26.70 36.68	50.30 26.40 33.56	NA	NA	NA	NA
Indurjeeth K [26]	South Africa, 2019	Diameter (mm) Depth (mm)	57.47 32.04	52.15 30.58	54.91 31.21	54.70 31.40	57.31 31.39	57.62 32.69	52.52 31.04	51.79 30.12
Pullanna B et al., [25]	Mangaluru, India, 2022	Diameter (mm) Depth (mm)	50.30 28.50	44.40 24.90	47.00 27.10	47.70 26.30	NA	NA	NA	NA
Arunkumar KR et al., [30]	Perambalur, India, 2021	Diameter (mm) Depth (mm)	NA	NA	48.76 23.60	49.20 24.60	NA	NA	NA	NA
Tripathi M and Gajbhiye V, [31]	Bhopal, India, 2022	Diameter (mm) Depth (mm)	NA	NA	48.62 25.36	48.48 25.46	NA	NA	NA	NA
Vyas K et al., [32]	Baroda, India, 2013	Diameter (mm) Depth (mm)	NA	NA	47.90 27.10	48.30 26.50	NA	NA	NA	NA

[Table/Fig-6]: Comparative analysis of morphometrical parameters [24-32].
NA: Not applicable

side was lower, while the left-side was found to be higher when compared with the observations of Rajilarajendran HS et al., (N=71) in the Chennai population [Table/Fig-6] [28]. An acetabular depth of less than 9 mm is clinically labeled as a dysplastic hip, and definitive OA complications can be anticipated. The mean depth of 22.94±2.91 mm in this study reflects the safer diagnostic limit. The least measured depth was found in the subgroup of right-sided acetabula of both genders and in female acetabula of both sides, with a safer value of 15.95 mm evidenced [30].

The mean acetabular diameter, depth and capacity, along with the statistically significant differences in means between males and females, as well as, between the right-sides of males and females and the left-sides of males and females, could aid forensic experts during postmortem gender identification. These findings would contribute to the database of biomedical engineers in the surgical instruments manufacturing sector, providing valuable information for designing acetabular prostheses for hemiarthroplasty procedures specific to the study population (a subset of the western Tamil Nadu population). This is important because implant failure due to prosthesis mismatch (incongruency in acetabular diameter and depth) can occur when the prosthesis is not designed for the target population.

In the present study, the curved type of AAR predominated at 50%, which is similar to findings from a study conducted by Gwala FO et al., (N=94) in the Nairobi population, Aksu T et al., (N=154) in the Turkish population, Vyas K et al., (N=152) in the Baroda population, Pullanna B et al., (N=100) in the Mangaluru population, Arunkumar KR et al., (N=104) in the Perambalur population, and Singh A et al., (N=92) in the Bareilly population [25,30,32-35]. The least represented type was the straight type (13%), which was similar to findings by Arunkumar KR et al., (N=104) in the Perambalur population [30]. However, this differed from other study populations, where the least represented type was angular, as seen in studies by Gwala FO et al., (N=94) in the Nairobi population [33] and Vyas K et al., (N=152) in the Baroda population [32]. The irregular type was the least represented in studies by Aksu T et al., (N=154) in the Turkish population [34], Pullanna B et al., (N=100) in the Mangaluru population [25], and Singh A et al., (N=92) in the Bareilly population [35] [Table/Fig-7] [25,30,32-35].

Authors	Place and year of study	Type of anterior acetabular ridge (Incidence in %)			
		Curved	Straight	Angular	Irregular
Present study	Coimbatore, India, 2015	50	13	17	20
Gwala FO et al., [33]	Nairobi, Kenya, 2020	34	21	20	25
Aksu T et al., [34]	Turkey, 2006	46	23	17	14
Vyas K et al., [32]	Baroda, India, 2013	38	32	12	18
Pullanna B et al., [25]	Mangaluru, India, 2022	39	22	24	15
Arunkumar KR et al., [30]	Perambalur, India, 2021	63	3	24	10
Singh A et al., [35]	Bareilly, India, 2020	46	15	26	13

[Table/Fig-7]: Comparative analysis of types of AAR [25,30,32-35].

Based on the type of AAR, the curved type has been reported as predominant, but there were differences in the least represented type. In the Tamil Nadu population, both the reference study by Arunkumar KR et al., (N=104) in the Perambalur population and the present study exhibited the straight type as the least prevalent, which may be due to the ethnic and geographical similarities among the samples [30]. This adds to the anthropological dataset. The irregular nature of the AAR may contribute to pincer impingement due to incongruency with the femoral head, potentially leading to dysplasia followed by OA. In the present study, 20% of the population had an irregular type of AAR, which may indicate a population at risk for impingement complications.

Limitation(s)

The limitation of the present study was that the sample size was based on resource constraints.

CONCLUSION(S)

The present study documented the acetabular parameters in a selected sample of dry bones, which could be useful for designing prosthetics in arthroplasty procedures and implies their clinical and anthropological significance, as significant differences were observed between males and females in all parameters. The most common type of curved AAR and the least common type of straight AAR might be associated with impingement and further complications of OA. The anthropometric parameters of the present study could be evaluated using methods alongside clinical features for further elucidation of the acetabular form and function.

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