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Morphologic And Morphometric Evaluation of Acetabulum of Hip Bone Among North Indian Population

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ABSTRACT

Background: Acetabulum is a deep cup-shaped cavity present on the lateral side of hip bone, where three small bones unite and fuse. It articulates with femoral head to form hip joint, a ball and socket variety of synovial joint. Acetabular cavity is divided into two parts: articular lunate surface and non-articular rough acetabular fossa. To design prosthesis in hip arthroplasty and for total hip replacement surgeries, knowledge of detailed morphometry and morphology of acetabulum is needed for orthopaedic surgeons.

Methods: Present observational study was conducted on 56 dry human hip bones of both sexes from the bone bank, Department of Anatomy, FMHS, SGT University, Gurugram, Haryana. Detailed morphometry of acetabulum including non-articular acetabular fossa and lunate surface was carried out with the help of digital vernier calliper whereas morphological features were observed by visual inspection.

Statistical analysis was performed by SPSS software latest version (version 21) to find mean, standard deviation along with p value and t value for bilateral comparison.

Results and discussion:

1. Mean transverse and vertical diameter of acetabulum on right side was 46.81 ± 3.64 mm and 52.86 ± 3.89 mm and 47.14±3.21mm and 52.73 ± 3.84 mm on left side respectively. Mean values of depth of acetabulum and width of acetabular notch was 24.07 ± 1.89 mm and 22.14 ± 4.32 mm on the right side and 24.22 ± 2.16 mm and 25.28 ± 5.77 mm on the left side respectively. Average values of transverse and vertical diameter of non-articular part of acetabular fossa was 28.33 ± 2.82 mm and 35.11 ± 2.57 mm on right side and 28.29 ± 2.47mm and 34.83 ± 3.75 mm on left side respectively.
2. Incidence of lunate shape of lunate surface at the posterior end was the maximum (91.1%) and curved shape of anterior acetabular ridge was the most common (42.9%). Significant bilateral asymmetry in the anterior end morphology of the lunate surface ($p < 0.05$) found.
3. No significant side preference in shape distribution of the anterior acetabular ridge seen. There are strong correlations between right and left measurements of main diameters of acetabulum. Width of acetabular notch shows significant bilateral difference, left side showing greater variability.

Conclusions: The data provides a detailed evaluation of morphometry and morphology of acetabulum, which is of immense help to orthopaedic surgeons for prosthesis design in hip arthroplasty. It will also enhance knowledge among radiologists in diagnosing pathological condition such as femoro-acetabular impingement.

Keywords: *hip bone; acetabulum; lunate surface; morphometry; hip arthroplasty*

1. INTRODUCTION

Hip bone is a large and irregular bone and is a part of pelvic girdle [1]. Posteriorly it articulates with sacrum to form sacroiliac joint whereas it forms the pubic symphysis anteriorly [2]. It is a combination of three small bones – ilium, ischium and pubis but in unequal proportions [3]. Acetabulum, a deep cup-shaped fossa situated on the lateral side of hip bone [4]. Obturator foramen, a large foramen lies anteroinferior to acetabulum between pubis and ischium [5]. It articulates with femoral head to form hip joint, a ball and socket variety of synovial joint; one of the most stable joint of the body [5,6]. Acetabular cavity comprises of two parts: articular and non-articular parts. A half-moon shaped, lunate surface forms articular part of it. Articular cartilage covers the lunate surface but acetabular fossa is devoid of any cartilage and is filled by fibroelastic fat pad [1,4]. Development of acetabulum begins from 4^{th} to 6^{th} week in utero and is completed by 8^{th} week. To perform proper biomechanism of hip joint, normal development of hip bone is mandatory [7]. Various pathological conditions such as acetabular dysplasia and femoro-acetabular impingement are associated with morphological deformities of acetabulum [8]. Acetabular dysplasia is characterized by a vertically oriented acetabulum with a shallow and underdeveloped roof, resulting in insufficient coverage of the femoral head [9,10]. Centre-edge angle is radiographically assessed and is normally used as a diagnostic criteria for distinguishing dysplastic hip from anatomically normal hip joint [11,12]. Among all congenital anomalies, displacement of hip joint is one of the commonest one; where head of the femur is not fitting properly inside the acetabular fossa resulting a malfunctioning hip joint. Accurate size of prosthesis for acetabular fossa is mandatory to regain functioning of the hip joint [13]. So, in total hip arthroplasty, an advanced reconstructive surgical procedure where not only femoral head and proximal neck are surgically excised with acetabular cartilage but also underlying bone is to be removed. Excised parts are then reconstructed by prosthetic hip components that include a metal femoral implant and an acetabular component [14]. Morphological variability especially curved, angular or irregular anterior acetabular ridge also have great influence in total hip arthroplasty. But the morphology of anterior acetabular ridge shows variations that affect the amount of anteversion and may end in iliopsoas impingement caused by chronic friction between iliopsoas tendon and rim of implant, after arthroplasty, as the prosthesis overlaps at the anterior acetabular ridge [15].

Another condition is femoro-acetabular impingement, in which due to increased depth of acetabulum and its retroversion results in over coverage of the head of femur [8,16,17]. Treatment includes surgical interventions such as trimming the rim of acetabulum, reversed periacetabular osteotomy etc. Total hip replacement is another successful surgical operation [16,17].

Given the practical implications, the aim of the present study was to assess the variation in morphology of acetabular ridge and morphometry of acetabulum.

2. MATERIALS AND METHODS

Study design and Data collection: The present study was observational in design, performed on morphometry and morphological variations of acetabulum. The sample size included 56 adult dry hip bones of both sexes obtained from bone bank of the Department of Anatomy, FMHS, SGT university, Gurugram over a period of one year. All hip bones were examined and anatomical parameters were recorded. The information of study materials were anonymised as coded so as to delink from any identity source (ICMR guideline: National Ethical guidelines for biomedical and health Research involving Human participants, ICMR, 2017 section 5, Box 5.2) [18]. Ethical committee approval was obtained from FMHS, SGT University.

Inclusion and exclusion criteria: All undamaged, fully ossified dry hip bones of both sexes were included in the study. Broken and apparently pathological hip bones were excluded from the observational evaluation.

The morphological variations such as end of lunate surface and shape of anterior acetabular ridge (curved, angulated, straight or irregular) were evaluated by visual inspection.

Morphometric measurements were made using digital vernier calliper. Measurements were made twice and mean was taken to reduce bias. The following measurements were performed for various bony landmarks:

1.Transverse diameter of acetabulum: Maximum distance between the anterior and

posterior ends of the acetabular cavity.

2. Vertical diameter of the acetabulum: Maximum distance between the upper and lower

margins of the acetabular cavity.

3. Depth of acetabulum: Maximum vertical distance from the deepest point in the acetabular cavity to the brim of the acetabulum.

4. Width of acetabular notch: Distance between the anterior and posterior end of the lunate articular surface.

Maximum width of lunate surface: This was measured at 3 levels: anterior-most, superior-most and posterior- most.

Transverse and vertical diameter of non-articular part of acetabular fossa

Sample size calculation

Sample size was calculated on the basis of prevalence stated by Bahl I et al [6] using the formula given below:

$N= z^2 \times p \times q/L^2 = (1.96)^2 \times 70 \times 14/73$: N = 51

Where Z=desired confidence level; L= population size; P= prevalence factor; q= margin of error. The required sample size was calculated to be 51.

Statistical analysis was performed using SPSS software latest version (version 21) to find mean, standard deviation as along with p value and chi-square test as tests of significance. A p-value of <0.05 was considered statistically significant.

Results: The morphometric parameters of acetabulum for both sides are shown in Table 1. The difference in the width of acetabular notch was found to be statistically significant between the two sides. Morphological parameters were assessed separately for lunate surface and the acetabular fossa. There was no statistically significant difference in these parameters between the two sides (Table 2).

Morphological parameters which included the shape of anterior acetabular ridge and lunate surface (anterior and posterior end) were noted (Table 3). Curved was the most common morphological pattern (42.9%) in both right and left sided anterior acetabular ridge. However, no statistically significant difference in distribution was observed between right and left sides, using the chi-square test (p=0.605).

With regard the anterior end of lunate surface, lunate (57.1%) was most common shape on the right side. On the left side, however, pointed was the most common shape (67.9%). There was a statistically significant difference between right and left sides using McNemar's test (p=0.041), suggesting asymmetry in anterior end morphology.

The posterior end of lunate surface displayed lunate as the most common (91%) shape on both left and right sides. In this case, there was no statistically significant difference between sides (p=0.248).

Fig-1a: Showing transverse diameter of acetabulum, b: vertical diameter of acetabulum, c: horizontal diameter of acetabular fossa, d: depth of acetabulum, e: width of acetabular notch

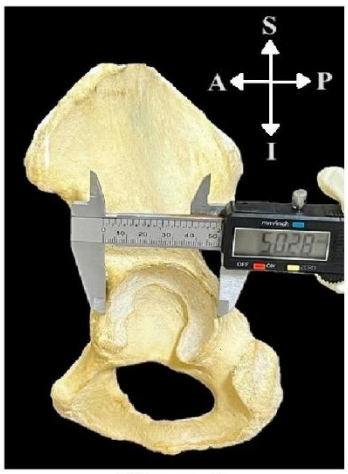


Figure-1a

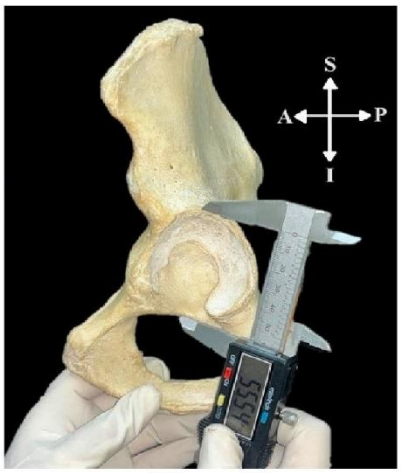
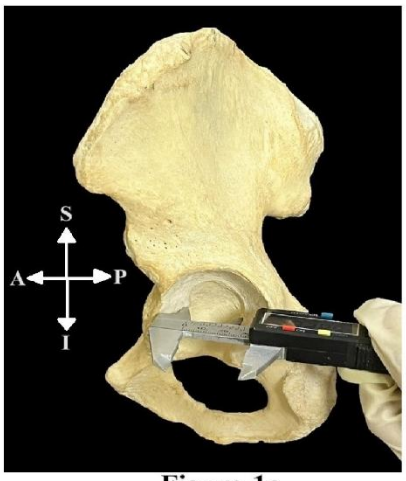


Figure-1b



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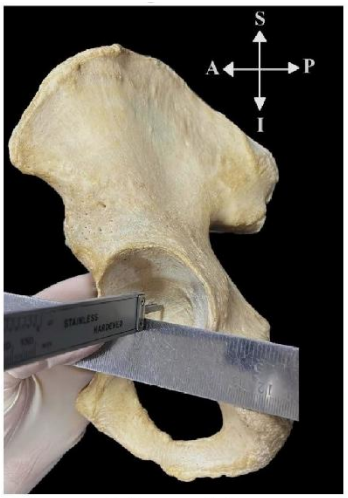

Figure-1d

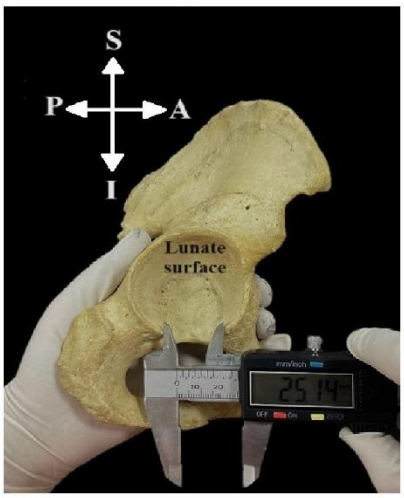

Figure-1e

Table 1: Morphometric parameters of acetabulum (transverse diameter, vertical diameter, total diameter, depth and width of acetabular notch) in mm

	Morphometric parameters of acetabulum (mm)	Mean ± SD (mm)		t-value (Student's paired t-test)	p-value
		Right	Left		
1.	Transverse Diameter	46.81 ± 3.64	47.14 ± 3.21	-0.427	0.673
2.	Vertical Diameter	52.86 ± 3.89	52.73 ± 3.84	0.156	0.877
3.	Total Diameter	49.84 ± 3.64	49.94 ± 3.31	-0.135	0.894
4.	Depth	24.07 ± 1.89	24.22 ± 2.16	-0.326	0.747
5.	Width of Acetabular Notch	22.14 ± 4.32	25.28 ± 5.77	-2.557	0.017*

Table 2: Morphological parameters for lunate surface and the acetabular fossa

	Lunate Surface (mm)	**Mean ± SD (mm)**		**t-value**	**p-value**
		Right	**Left**		
1.	Anterior Most Part	21.14 ± 2.46	21.38 ± 2.24	-0.421	0.677
2.	Superior Most Part	25.53 ± 2.72	25.31 ± 2.41	0.368	0.716
3.	Posterior Most Part	20.73 ± 2.89	20.22 ± 2.55	0.795	0.433
	Acetabular Fossa (mm)	**Mean ± SD (mm)**		**t-value**	**p-value**
		Right	**Left**		

1.	Transverse Diameter	28.33 ± 2.82	28.29 ± 2.47	0.065	0.949
2.	Vertical Diameter	35.11 ± 2.57	34.83 ± 3.75	0.368	0.716

Table 3: Frequency of morphological parameters of acetabulum, n=56

SN	**Morphologic parameters**	**Side**	**Frequency, n (%)**	
1.	Shape of Anterior Acetabular Ridge	Right	Curved	13 (46.4%)
			Angular	6 (21.4%)
			Straight	5 (17.9%)
			Irregular	4 (14.3%)
			Total	28 (100%)
		Left	Curved	11 (39.3%)
			Angular	6 (21.4%),
			Straight	4 (14.3%)
			Irregular	7 (25%)
			Total	28 (100%)
2.	Anterior End of Lunate Surface	Right	Lunate	16 (57.1%)
			Pointed	12 (42.9%)
		Left	Lunate	9 (32.1%)
			Pointed	19 (67.9%)
3.	Posterior End of Lunate Surface	Right	Lunate	24 (85.7%)
			Pointed	4 (14.3%)
		Left	Lunate	27 (96.4%)
			Pointed	1 (3.6%)

3. DISCUSSION

Detailed morphological description of acetabulum is crucial for the selection of proper sized prosthesis in total hip arthroplasty. Different types of acetabular ridge play a vital role in successful hip arthroplasty procedure. Studies have been conducted in other population groups such as Turkish [19], African [20], Nigerian [21] as also among Indian population [6, 22, 23, 24] to evaluate morphological parameters. A review of these studies is presented in Table 4. In the present study, the morphological variability has been performed in North Indian population group. We found the incidence of curved shaped anterior acetabular ridge to be the highest, similar to the observations made by Singh A et al [23], Bahl I et al [6], Govsa et al [19], Aksu et al [25].

Table 4: Review of literature on shape of anterior acetabular ridge in different population groups

Author & year	**Population**	**No. of bones**	**Morphologic parameters of acetabulum**
			Number (%) of shape of anterior acetabular ridge

			Curved	**Angular**	**Straight**	**Irregular**
Govsa F et al [19] (2005)	Turkey	226	98 (43.36 %)	64 (28.33 %)	27 (11.94 %)	37 (16.47 %)
Aksu FT et al [25] (2006)	Dokuz (Turkey)	154	71 (46.1 %)	26 (16.8 %)	36 (23.3 %)	21 (13.6 %)
Ukoha UU et al [21] (2014)	Nigeria	100	35 (35 %)	33 (33 %)	23 (23 %)	9 (9 %)
Indurjeeth K et al [20] (2019)	African	100	22 (22 %)	41 (41 %)	14 (14 %)	23 (23 %)
Singh A et al [23] (2020)	Uttar Pradesh	92	42 (45.7%)	24 (26.1%)	14 (15.2%)	12 (13%)
Bahl I et al [6] (2020)	Bangalore	73	30 (41.1%)	19 (26.2%)	4 (5.5%)	20 (27.4%)
Pullanna B et al [24] (2022)	Karnataka	100	39 %	24 %	22 %	15 %
Tripathi M et al [22] (2022)	Bhopal	200	100 (50%)	60 (30%)	10 (5%)	30 (15%)
Ülkir M et al [26] (2023)	Turkey	100	18 (31.6%)	14 (24.6%)	19 (33.3%)	6 (10.5%)
Present study	North Indian	56	24 (42.9%)	12 (21.4%)	9 (16.1%)	11 (19.6%)

Table 5: Review of literature on morphometric parameters of acetabulum in different population groups

Author and year	Population group	No. of bones	Side of bone	Morphometric parameters of acetabulum			
				Transverse	Vertical	Depth	Notch width
Ukoha UU et al [21] (2014)	Nigeria	100	Rt.	5.39 ± 0.35 cm	5.58 ± 0.37 cm	2.97 ± 0.31 cm	_
			Lt.	5.32 ± 0.33 cm	5.46 ± 0.30 cm	3.02 ± 0.31 cm	_
Yugesh K et al [7] (2016)	South Indian	60	Rt.	47.4 ± 0.27 mm	_	29.9 ± 0.21 mm	30.8 ± 0.42 mm
			Lt.	48.0 ± 0.37 mm	_	29.7 ± 0.23 mm	31.1 ± 0.72 mm
Purohit K et al [27] (2018)	North Indian	57	Rt.	5.3 ± 0.43 cm	_	2.3 ± 0.36 cm	2.2 ± 0.45 cm
			Lt.	5.5 cm ± 0.38 cm	_	2.6 ± 0.43 cm	2.2 ± 0.50 cm
Indurjeeth K et al [20] (2019)	African	100	Rt.	_	57.31 ± 3.37mm	31.39 ± 2.80 mm	21.85 ± 3.42 mm
			Lt.	_	57.62 ± 3.14 mm	32.69 ± 3.42 mm	22.73 ± 3.33 mm
Singh A et al [23] (2020)	Uttar Pradesh	92	Rt.	47.43 ± 3.43 mm	48.00 ± 3.56 mm	26.73 ± 3.06 mm	23.11 ± 2.70 mm
			Lt.	48.13 ± 3.33 mm	48.38 ± 3.12 mm	28.04 ± 2.88 mm	23.98 ± 2.79 mm
Pullanna B et al [24] (2022)	Karnataka	100	Rt.	4.7 ± 0.39 cm	_	2.71± 0.35 cm	1.92 ± 0.45 cm
			Lt.	4.77± 0.47 cm	_	2.63 ± 0.31 cm	1.86 ± 0.4 cm
Ülkir M et al [26] (2023)	Turkey	57	Rt.	51.14 ± 3.42 mm	52.87 ± 3.36 mm	29.80 ± 2.24 mm	22.03 ± 2.43 mm
			Lt.	50.21 ± 2.80 mm	51.56 ± 3.60 mm	29.70 ± 2.36 mm	23.23 ± 2.79 mm
Soman MA et al [4] (2023)	Mangalore (Karnataka)	200	Rt.	48.57 ± 3.56 mm	51.21 ± 3.72 mm	26.14 ± 3.41 mm	_
			Lt.	45.69 ± 3.22 mm	47.34 ± 3.02 mm	24.22 ± 3.85 mm	_
Present study	North Indian	56	Rt.	46.81 ± 3.64 mm	52.86 ± 3.89 mm	24.07 ± 1.89 mm	22.14 ± 4.32 mm
			Lt.	47.14 ± 3.21 mm	52.73 ± 3.84 mm	24.22 ± 2.16 mm	25.28 ± 5.77 mm

Only a few studies have reported variability on the morphology of ends of lunate surface in acetabulum of hip bone. In our study, detailed morphology was evaluated and we concluded that pointed anterior end (55.4%) and lunate posterior end (91.1%) were most common. This is similar to the observations made by Singh A et al [23].

Relevance of the study: To the best of our knowledge, very few studies have been conducted on morphological parameters such as shapes of anterior and posterior ends of lunate surface especially among North Indian population group. Apart from that, morphometric parameters of acetabular fossa have also not been found among North Indian population group. As, morphometry of acetabulum play a predominant role in the successful placement of implants in total hip arthroplasty, so, detailed morphologic and morphometric evaluation of acetabulum holds a great clinical importance for anatomist, anthropologists and clinicians especially orthopaedic surgeons. For surgical planning, contralateral side measurements can be reliable references. High bilateral symmetry supports use of standardized implants. Special attention needed for acetabular notch width assessment as its variation may affect component positioning and influence implant selection and positioning. Surgical planning should account for the likely asymmetry in anterior lunate surface morphology. The posterior end's consistent lunate shape could be important for prosthetic design. The variability in anterior acetabular ridge morphology suggests need for individualized assessment.

4. CONCLUSIONS

Detailed morphologic and morphometric evaluation on both sided hip bones have been conducted in this present observational study. It is expected that, the data will act as baseline information for the clinicians to diagnose various pathologies related to hip joint. Also, this observation will be a great help in planning and placement of implants in hip arthroplasty with minimum postoperative complications.

5. LIMITATIONS AND FUTURE SCOPE OF THE STUDY

The study has been conducted on 56 dry hip bones of unknown sexes by convenience sampling, but future research can be performed on larger number of sample size with sexual dimorphism for a more elaborate result. Apart from that, radiological evaluation along with osteology can also be incorporated not only for better clinical diagnosis but also for choosing therapeutic procedure.

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Conflict of interest: None

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Supervision- Prachi Saffar Aneja

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Critical review- Nidhi Lal, Prachi Saffar Aneja

Article editing- Susmita Saha, Nidhi Lal

Final approval- Prachi Saffar Aneja, Susmita Saha

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