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Original Article

Anatomy Section

Detailed Morphometry and Morphology of Bicipital Groove of Humerus among North Indian Population

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ABSTRACT

Introduction: Bicipital Groove (BG) represents an indentation on the proximal humerus which lodges tendon of Long Head of Biceps (LHB) brachii with synovial sheath. It's medial and lateral walls are formed by lesser and greater tubercles respectively and the transverse humeral ligament converts it into a tunnel.

Aim: To find a detailed morphometry attributing to morphological classification of BG among North Indian population.

Materials and Methods: The present observational study was conducted over a period of one year on 100 adult intact dry humerii of unknown sexes obtained from Osteology Museum, Department of Anatomy, Shree Guru Gobind Singh Tricentenary (SGT) University, Gurugram, Haryana, India for several morphometric parameters like length, width, depth, length of medial and lateral walls as per descriptive statistics using Statistical Package for the Social Sciences (SPSS) version 21.0. The BG was classified according to the depth, opening angle and medial wall angles. Morphological features like Supratubercular Ridge (STR) of Meyer's, bony spur on the floor of the groove or thickening of the walls were also observed and the frequency distribution was presented and Independent t-test was applied to compare the parameters on both sides.

Results: Out of 100 sample, the mean of each parameter was length 72.98±7.54 mm, width 9.12±2.18.mm, depth 5.49±1.56 mm, medial wall and lateral wall length 54.83±8.62 mm and 60.82±8.01 mm respectively, opening angle 72.27±18.12° and medial angle 65.27±10.71°. Mostly BG had a depth of 4-6 mm with an incidence of 48%. Opening angle of BG was small (<95°) in 84% of humerus and maximum belonged to type 1 (90° to 75°) variety. Around 34% bones were showing morphological changes, out of which STR was 47.05%, bony spur on the floor of BG was 20.58% with wall thickening in 32.35% of total humerus.

Conclusion: The detailed morphometry and classification of BG will serve as a reference base for North Indian population. It will be also useful for the clinicians as they should be well verged with the various morphological appearances of BG among dry bones and radiographs for proper diagnosis and treatment.

Keywords: Bony spur, Long head of biceps, Morphological variations, Proximal humerus, Supratubercular ridge

INTRODUCTION

Bicipital groove (BG), also known as the intertubercular sulcus, is identified as an indentation at the anterior aspect of the proximal end of humerus [1]. It is located between greater and lesser tubercle on its lateral and medial aspects respectively and bounded superiorly by the transverse humeral ligament [2]. It is continuous with the rotator cuff which is one of the protecting factors of stability of the shoulder joint. The sulcus converted into a canal to pass the LHB brachii along with the synovial sheath [1]. Anatomical variations related to LHB in the BG were predisposing factors for frequent causes of shoulder pain leading to disability of shoulder joint [3]. The LHB and BG both are intimately related as variability of the shape of the BG may become predisposing factors for tear, impingement or subluxation of LHB [4]. Marked anatomical variations in this region are observed which was described by Rockwood CA and Masten FA [5].

Morphometric parameters of BG may have a great influence on the proper functioning of surrounding structures of shoulder joint [6]. Among all parameters, BG depth and width and angulations are holding a great importance in preventing subluxation or impingement of LHB causing shoulder pain [5]. Subluxation of LHB is very common in persons having a shallow BG especially medial subluxation [2,7,8]. In case of a deficient anatomic BG, there might be dislocation of LHB tendon [8]. Lateral dislocation or subluxation is less commonly seen. Apart from dislocation or subluxation, a deep narrow BG mostly becomes a root cause for the compression of LHB tendon present in it leading to impingement syndrome which is one of the most common functional disability of the shoulder joint [5].

BG and proximal portion of LHB tendon abnormalities have to be considered an important causative factor for pain shoulder. Abnormalities like tenosynovitis, subluxation or tear in the proximal segment of LHB tendon are commonly encountered in clinical practices [9]. The STR of Meyer's a bony excrescences present in the region of BG continuous with the lesser tubercle in its proximal aspect [10]. This was first described by Meyer's and later by Hitchcock HH and Bechtol CO in 1948. It also termed as a factor to prevent medial displacement of LHB which is much more common. Other bony proliferations like spur in the floor and any of the walls of the groove may be associated with possible damage of LHB tendon [3,4,10].

Osteometry of BG also acts as an important landmark for shoulder replacement surgeries and considered as a great help in not only designing but also placement of shoulder prosthesis as shoulder joint is the most mobile and least stable joint, need synchronised movement [11].

Though shoulder pain is multifactorial, its association with LHB tendon is commonly observed and may attribute to inflammatory conditions like tenosynovitis, subluxation and tendon tear [10,12,13]. So keeping all these cases in mind and considering the increasing number of cases of shoulder pain, a detailed morphometry and classifications of BG have been proposed. In the present study, various objective methods have been applied which is expected to be more authentic regarding the baseline morphometric data of BG. So, to the best of our knowledge, incorporation of all methods together to get a more elaborate result, this will enlighten the anatomy of BG morphology. Moreover, the present study will be a great help for the clinicians to diagnose as well as to manage patients with shoulder disabilities.

MATERIALS AND METHODS

The present observational study was conducted on 100 adult humerii of unknown sex from the Osteology Museum Department of Anatomy, SGT Medical College, Gurugram, Haryana, India for a period of one year from April 2020 to March 2021.

Sample size calculation: Taking the value as reference according to Wafae N et al., the minimum required sample size was calculated. Formula used was $N=z^2Pq/L^2$ [14]. Where, N is estimated sample size; z is confidence interval of 95%; P is percentage; q is (1-P); L is the permissible marginal error at 95% confidence interval and 80% power of the study.

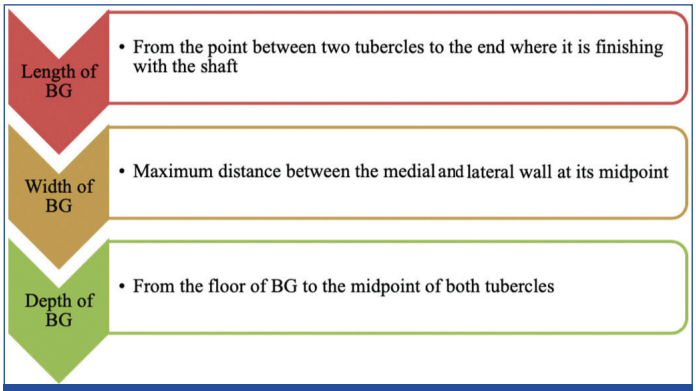
$N=4\times0.80\times(1-0.80)/0.08)^2=100$ (final sample size).

Sample was calculated by non probability sampling by convenient sampling method.

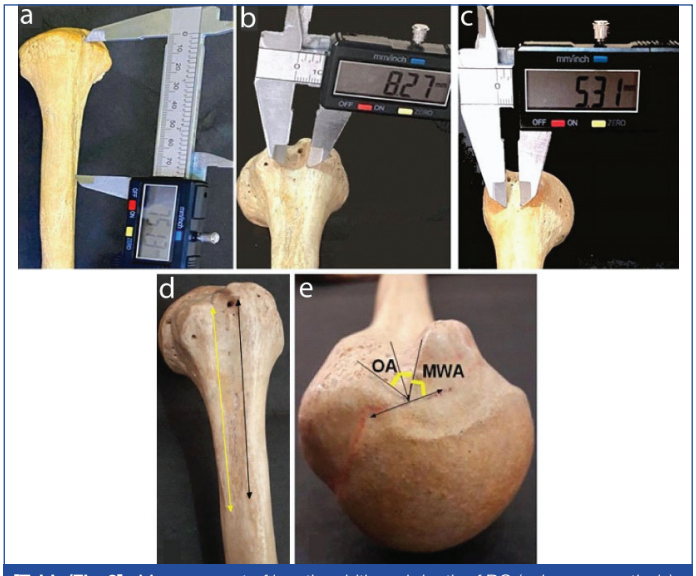
Inclusion criteria: Only dry specimens without any gross evidence of pathologies were selected as study materials available in the departmental museum.

Exclusion criteria: All broken and pathologically deformed humerii were excluded from the study.

The specimens were anonymised, randomly coded and de-linked from any identity sources (Indian Council of Medical Research {ICMR} National guidelines for biomedical and health research involving human participants, ICMR, 2017, sec 5, Box 5.2) [15]. Detailed morphometry with classification of BG and morphological variations were observed. Morphometric parameters such as length, width, depth, length of medial and lateral wall of BG were measured by the help of a digital vernier caliper in millimeters (shown in [Table/Fig-1]. Morphological features were observed by subjective evaluation (visual observation) [Table/Fig-2].

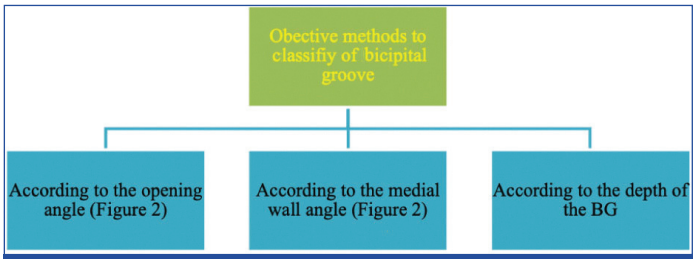


[Table/Fig-1]: Flow chart describing the measurement of length, width and depth of BG.



[Table/Fig-2]: Measurement of length, width and depth of BG (a, b, c respectively); measurement of medial wall (yellow arrow) and lateral wall (black arrow) length; (d) Measurement of opening angle and medial wall angle of BG; (e) OA and MWA, respectively.

Also, lengths of medial and lateral wall distances were measured from the tubercles to the respective walls of BG. The medial wall angle and opening angle were calculated for the all specimens to classify BG into different categories. Various objective parameters used for the classification the BG are given in [Table/Fig-3].



[Table/Fig-3]: Various morphometric parameters used to classify BG.

Different morphometric parameters were used to classify BG according to previous studies [3,4,14] separately, whereas in the present study these have been applied together [3,4,14].

According to the opening angle: According to Wafae N et al., opening angle was considered as small (≤95º); intermediate (95º-116°) and large (≥116°) [14].

According to medial wall angle: Bones were categorised from type 1 to type 6 based on Hitchcock HH and Bechtol CO classification: To categorise the bones according to medial wall angle as Type 1 to Type 6 was performed as Hitchcock HH et al., classification (Type 1: 90°, Type 2: 75°, Type 3: 60°, Type 4: 45°, Type 5: 30° and Type 6: 15°) [3].

According to the depth of BG: Based on the depth of BG as done by Rajapriya V et al., and Cone RO et al., bones were distributed into three categories: depth ≤3 mm, 4-6 mm and >6 mm, respectively [4,7].

Various morphological features such as presence of STR of Meyer's, thickening of the walls and presence of bony excrescences or spur in the floor of BG were also noticed among all the specimens by visual inspection and their incidence was calculated in percentages. For proper documentation, photography was performed which is displayed in the results section.

STATISTICAL ANALYSIS

All the morphometric parameters were measured twice to reduce error and the average was taken. Data obtained from the study was tabulated and analysed using SPSS software version 21.0. Maximum, minimum, mean with standard deviation for each osteometric parameter was calculated and presented according to the side of the bones. Independent t-test/unpaired t-test value as t-value was presented to compare the parameters on both sides. Also, p-value was mentioned to find out level of significance, p-value ≤0.05 was considered as significant.

RESULTS

In the present study, out of total 100 dry humerii, 57 humerii were of right side and 43 were of left side. The mean values of different morphometric parameters irrespective to their sides were length 72.98±7.54 mm, width 9.12±2.18 mm, depth 5.49±1.56 mm, medial wall and lateral wall length 54.83±8.62 mm and 60.82±8.01 mm, opening angle 72.27±18.12° and medial angle 65.27±10.71º The maximum, minimum, mean and standard deviation of each parameter according to their sides along with t-value and p-value (p-value ≤0.05 was termed as significant) for comparison are shown in [Table/Fig-4]; significant difference was observed in the width and opening angle of BG on both sides (p-value=0.001) and also for length of lateral wall of BG (p-value=0.018).

The BG was also grouped according to their opening angle into three varieties like small, intermediate and large. Their percentages are displayed in [Table/Fig-5]. The BG was classified according to

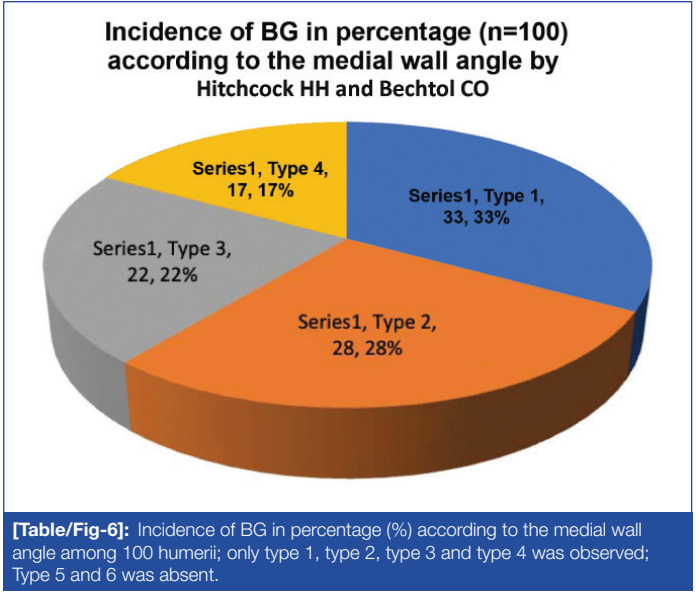
Parameters of bicipital groove	According to sides of bones	Minimum (mm)	Maximum (mm)	Mean±SD (mm)	t-value	p-value
Length	Right	53.92	97.63	71.81±6.98	1.804	0.074
	Left	59.72	90.12	74.53±8.04		
Medial wall length	Right	33.6	69.09	53.33±10.12	2.026	0.046
	Left	37.28	80.56	56.80±5.60		
Lateral wall length	Right	44.29	66.42	59.19±9.05	2.396	0.018*
	Left	51.29	76.71	62.98±5.81		
Width	Right	5.85	13.51	8.42±1.84	3.898	0.001*
	Left	6.43	14.73	10.03±2.27		
Depth	Right	3.25	8.47	5.85±1.15	1.049	0.297
	Left	3.42	10.43	5.61±1.15		
Opening wall angle	Right	54.00	115.00	77.47±17.38	3.745	0.001*
	Left	51.00	120.00	65.37±17.04		
Medial wall angle	Right	49.00	88.00	64.82±7.47	0.477	0.634
	Left	41.00	90.00	65.86±13.97		

[Table/Fig-4]: Descriptive statistics of the morphometric parameters of BG on both sides of humerus (in mm).
*Significant (p-value ≤0.05)

their depth into three categories ≤3 mm, 4 to 6 mm and >6 mm and their frequencies were 15%, 48% and 37%, respectively among total humerii. Medial wall angle was also used to segregate the bones into six various types and most common was type 2 BG observed in the present study [Table/Fig-6]. Type 5 and 6 of BG (medial wall angle of 30° to 15°) was totally absent in the present study.

Classification of BG by objective methods		Right n (%)	Left n (%)	Total N (%)
According to the opening angle	Small (<95°)	47 (82.46%)	37 (86.4%)	84 (84.00%)
	Intermediate (95-116°)	10 (17.54%)	5 (11.3%)	15 (15.00%)
	Large (>116°)	0	1 (2.32%)	1 (1.00%)
	Total	57 (100.00%)	43 (100.00%)	100 (100.00%)

[Table/Fig-5]: Frequency distribution of BG according to the opening angle into three categories.

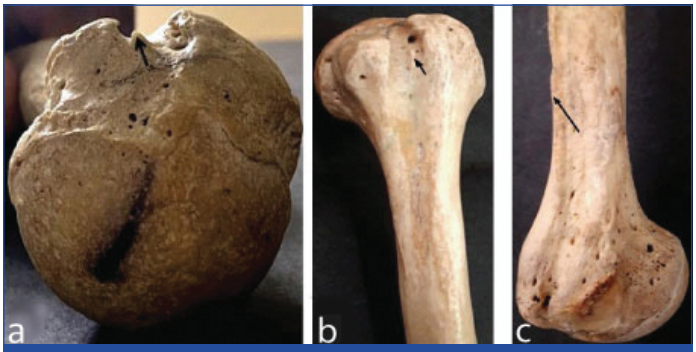


[Table/Fig-6]: Incidence of BG in percentage (%) according to the medial wall angle among 100 humerii; only type 1, type 2, type 3 and type 4 was observed; Type 5 and 6 was absent.

Out of 100 specimens, a total of 34 bones showed morphological changes. The STR of Meyer's was noticed on 16 bones, out of which 12 were of right and four bones were of left side. Other morphological variations like incidence of bony spur in the floor of BG was visible in 20.58% of specimen and thickening of walls of BG were also observed among 11 bones which come around 32.35% of total specimens. Mostly changes were evident on the right side as shown in [Table/Fig-7]. Various morphological features of BG were observed and their photographs were presented in [Table/Fig-8].

Morphological features	Right n (%)	Left n (%)	Total N (%)
Supratubercular ridge of Meyer's	12 (75%)	4 (25%)	16 (47.05%)
Bony spur in the floor of BG	5 (71.3%)	2 (28.57%)	7 (20.58%)
Thickening of wall of BG	6 (54.5%)	5 (45.45%)	11 (32.35%)
Total bones with morphological changes	23 (67.5%)	11 (32.35%)	34

[Table/Fig-7]: Incidence of BG with morphological changes (Maximum frequency was observed for the presence of supratubercular ridge of Meyers').



[Table/Fig-8]: Various morphological features of BG a) Supratubercular ridge of Meyer's; b) Bony spur in floor of the groove; c) Thickening of wall of BG.

DISCUSSION

The BG or intertubercular sulcus is present between lesser and greater tubercle of humerus and extends distally almost 5 cm on the shaft of the humerus containing LHB tendon with its synovial sheath and ascending circumflex humeral artery [1]. The tendon of LHB plays a crucial role in maintaining the alignment of head of humerus with glenoid cavity. Any variability in its position may lead to varieties of shoulder disabilities [16]. Structural variation of BG may cause sliding of LHB from the floor of the groove; commonly seen in persons with a very shallow groove [2,3,8]. As shoulder joint is the most mobile but least stable joint of the body, its rotational movement with a very shallow BG might be a reason for trauma to the tendon of LHB as it easily gets impinged on acromion, coracoacromial ligament and coracoacromial arch [16]. It was also observed in previous research that, variation of morphometric parameters and morphological changes of BG have been termed as to develop biceps tendinitis; one of the common causes of shoulder deformity with pain shoulder [17]. Apart from clinical concerns, knowledge regarding morphometry of BG holds a useful landmark for shoulder replacement surgeries for proper fitting of prosthesis [1]. Studies have also mentioned that BG parameters serve a major role in proximal humeral replacement procedures [11,18]. It was also described by Patel DK et al., in their cadaveric study that, extra head of LHB tendon might be present in the BG as an anatomical variation which may be of clinically important [19]. It should be remembered while diagnosing shoulder disabilities in patients and also for treatment of shoulder surgeries. It was also explained in many previous studies that, a combination of narrow BG with a presence of STR of Meyer's can be one of the potential reasons for biceps tendon disorders specially biceps tendinitis or subluxation [10,20]. Even a very long wide BG may lead to sliding of LHB tendon from its actual position leading to bicipital dysplasia [12].

In the present study, the length of BG irrespective to the sides was 72.98±7.54 mm which was almost similar as studies done by Wafae N et al., [14]. In study done by Gupta S et al., the length was around 2.9 cm which was much higher than our observation [21]. But the mean width of BG in this study was 9.12 mm which was as in consonance with studies performed by Arun kumar KR et al., Singh R and Singh M, Wafae N et al., and Muralimanju BV et al., [18,22,14,23]. But study performed by Vettivel S et al., and, Rajan YS and Sampath SK, the average width was very less [24,25]. In the present study result, it showed a higher width on the left side bones as compared to right. The depth in the present morphometry was 5.49 mm on an average; similar as Arun kumar KR et al., Singh R and Singh M, but in other evaluation it was very less near about 4 mm to 5 mm on an average

Authors (year)	Place of study	Sample size	Length	Width	Depth	Medial wall length	Lateral wall length
Cone RO et al., [7] (1983)	Peru	54			4.3 mm		
Levinsohn EM and Santelli ED [12] (1991)	New York USA	55		7 mm	5 mm		
Vettivel S et al., [24] (1992)	Vellore	200			Right-3 mm		
					Left-6 mm		
Wafae N et al., [14] (2010)	Brazil	50	8.1 mm	10.1 mm	4 mm		
Muralimanju BV et al., [23] (2012)	Mangalore	104	84.6±10.9 mm	8.5±2.3 mm	4.4±1.8 mm		
Singh R and Singh M [22] (2013)	Uttar pradesh	101	Right-85 mm	9 mm	5 mm	22±4 mm	31.6±6 mm
			Left-83 mm	8.9 mm	6 mm	23±5 mm	31±5 mm
Prajakta K et al.. [26] (2014)	Loni (Uttar pradesh)	164		5.5 mm	9.4 mm	6.43 cm	8.77 cm
Gupta S et al., [21] (2015)	Jammu	100	2.9 cm	1.77 cm	0.4 cm		
Arun Kumar KR et al., [18] (2016)	Kolkata	98	83 mm	8.4 mm	5 mm	Right-23±3 mm	30±2 mm
						Left-24±3 mm	32±6 mm
Rajan YS and Sampath SK [25] (2016)	Chennai	100	84 mm	6.8 mm	4.2 mm	24.22±1.02 mm	32.5±2.21 mm
						23.31±2.2 mm	31.1±0.24 mm
Rajapriya V et al., [4] (2017)	Kilpauk	200	8.18 cm	8 mm	4.6 mm		
Ashwini ZA et al., [27] (2017)	Karnataka	87	Right-89.94 cm	8.53±1.6 cm	6.48±1.3 cm	81.72±6.4 cm	89.61±6.03 cm
			Left-88.8 cm	7.96±1.9 cm	6.14±1.4 cm	79.56±4 cm	89.15±8.27 cm
Present study (2021)	Gurugram (North India)	100	Right-71.81±6.98 mm	8.42±1.84 mm	5.85±1.15 mm	53.33±10.12 mm	59.19±9.05 mm
			Left-74.53±8.04 mm	10.03±2.27 mm	5.61±1.15 mm	59.19±56.80 mm	62.98±5.81 mm

[Table/Fig-9]: Comparative analysis of morphometric parameters of BG among different population group [4,7,12,14,18,21-27].

[18,22]. Vettivel S et al., found BG with very small depth especially on the right side which was only 3 mm among South Indian population and in a study by Prajakta K et al., the depth was very high [24,26]. Hence, a detailed morphometry of BG was conducted and reviewed with the existing literature in [Table/Fig-9] [4,7,12,14,18,21-27].

In very few studies, length of medial and lateral walls was measured except Arun kumar KR et al., Rajan YS and Sampath SK, Ashwini ZA et al., where the measurement was higher as compared to the present results [18,25,27]. Present results reflect on North Indian population but the above studies are on South Indian and Eastern population group. The opening angle in this study was 72.72°±18.18 which was similar as Arun kumar KR et al., Singh R and Singh M [18,22]. But Wafae N et al., found a very wide opening angle which was almost 106º among Brazilian population [14]. On the other hand, Rajapriya V et al., and Vettivel S et al., found BG with small opening angle of 60º and 62º respectively [Table/Fig-6] [4,24]. The opening angle was also used to classify the BG into 3 categories; small, intermediate and large according to Wafae N et al., [14]. In our study, maximum BG showed ≤95° as small categories but Wafae N et al., found BG with opening angle of 106° which was rarely seen in other studies [14].

Finally the medial wall angle was measured in the present morphometric analysis where it came around 65.27±10.71° which as same as Ashwini ZA et al., [27]. Hitchcock HH and Bechtol CO mentioned BG having a range of 15° to 90° and they categorised the BG according to the medial wall angle into six categories [3]. They also concluded a shallow BG with medial angle less than 45 degree in 8% of normal humerii may predispose to dislocation of tendon of LHB which was also supported by Meyer's radiological evaluation where LHB dislocated in very shallow BG leading to rotator cuff tear visualised in the radiographs [10]. In the present study, type 5 and 6 categories of BG were absent and was concluded that most of the BG (48% of total sample) were from 75° to 90°.

Apart from these, the depth of BG was also utilised to categorise the BG into three types according to Cone RO et al., where it was 86% of total sample showing depth of 4 to 6 mm [7]. Similarly, authors also found the maximum incidence of BG with the same distance. But in this study, the incidence of BG having >6 mm depth was high (37%) which was very less in studies performed by Rajapriya V et al., and Cone RO et al., on population of San Diago even in among South Indian population [4,7].

Morphological characteristics were also observed among the study sample by visual inspection and 34 bones showed special morphological characteristics. Out of 47.05% bones showed STR of Meyer's, more seen on the right sided bones which was as similar as Hitchcock HH and Bechtol CO, Singh R and Singh M, and, Rajan YS and Sampath SK, found a higher incidence of supratubersular ridges [3,22,24,25]. The frequency was very less noticed in Gupta S et al., and Muralimanju BV et al., studies [21,23]. In this study most of the bones were of right side, which was in consonance with other studies performed by Arun kumar KR et al., and Gupta S et al., Muralimanju BV et al., [18,21,23]. Cone RO et al., in their radiological evaluation, interpreted the presence of STR and its incidence on 50% of all cases [Table/Fig-10] [4,7,18,21-25,27].

Authors	Years	Population	Sample size	Right (%)	Left (%)	Total (%)
Cone RO et al., [7]	1983	San Diego	54	88%	57%	
Vettivel S et al., [24]	1992	Vellore, India	200			50%
Muralimanju BV et al., [23]	2012	Mangalore	104	15.4%	7.71%	23.1%
Singh R and Singh M et al., [22]	2013	Manglore	100	71%	29%	42%
Gupta S et al., [21]	2015	North India	82	18.1%	8.4%	26.5%
Arun kumar KR et al., [18]	2016	Kolkata	100	17.1%	14%	
Rajan YS et al., [25]	2016	South India	200	28%	30%	58%
Ashwini ZA et al., [27]	2017	Kilpauk	101	17%	20%	37%
Rajapriya V et al., [4]	2017	Karnataka	87	87.17%	85%	
Present study	2021	North India	100			47%

[Table/Fig-10]: Incidence of Supratubercular Ridge (STR) of Meyer's among different other population group [4,7,18,21-25,27].

The bony excrescence or groove spur was seen in 11 specimens (32.3%) of total 34 bones mostly on the right side as seen in Ashwini ZA et al., [27]. Cone RO et al., also identified medial wall spur in their radiological evaluation among 171 among cases [7]. They also concluded that, STR and bony spur were more on the

right side to present the medial displacement of LHB from the groove leading to subluxation.

Apart from subluxation of biceps tendon, tenosynovitis or tendon tear may be also frequently associated with the presence of bony spur or osteophytes and STR [7,28]. Spurs type of anatomic variant is not usually detectable in arthrography but usually described as radiographic findings and well associated with rotator cuff lesions and must be assumed to be an important factor for bicipital tenosynovitis [29]. So, this type of anatomic variant should be remembered while clinical examinations and radiographic evaluations.

Morphometric parameters of BG are playing major role for shoulder replacement surgeries and considered as a great help in designing shoulder prosthesis to maintain synchronised movement of shoulder joint to restore normal daily activities [11]. Also, BG morphometry acts as an anatomic landmark for reconstructive complex proximal humeral fractures [30].

Limitation(s)

In the present study, authors have studied the morphometric and morphological evaluation of BG irrespective to the sexes which can be performed later. Also, the number of dry specimens can be increased as sample size for the further studies to ensure more valid results along with radiographic correlations.

CONCLUSION(S)

The present study evaluates detailed morphometry attributing to morphological classification of BG of humerus among North Indian population, providing an anatomical baseline to correlate the radiologic findings with clinical presentations. Objective methods of classifying BG bear a great importance to find out the pathogenesis of compression or displacement of LHB present in the groove. This will assist clinicians to decide the modalities of treatment. Also, morphometric data will especially facilitate the orthopaedic surgeons to devise appropriate operative strategy, so that the functionality of the shoulder joint can be restored. The morphometric and morphological evaluations of BG among dry humerii can be synchronised with radiographic analysis of different shoulder pathologies in near future to provide a better result for clinical cases.

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