Original Article

Morphometry of the Bicipital Groove Revisited: A Radiographic Study

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Abstract

Background: With increased prevalence of proximal humeral fractures, providing a precise assessment of different measurements for the bicipital groove and testing the gender differences on the same side bicipital groove in addition between different sides on the same gender become mandatory. **Methodology:** Three hundred and ten shoulder magnetic resonance imaging scans were used in this study, these scans obtained from January 2020 to December 2021. These images include; 155 for males and the same number for females, 190 for the right side in addition 120 for the left side. Statistical Package for Social Science (SPSS) were used to analyze the data, independent *t*-test was conducted, $P < 0.05$ was decided to be statistically significant. **Results:** There was significant difference ($P < 0.05$) between different genders in terms of depth and width of bicipital groove, distance between greater and lesser tubercles. In addition, significant difference found between different sides in terms of depth of intertubercular groove and the distance between tubercles. **Conclusion:** As a result of variations among different population, obtaining an accurate morphometry of proximal humerus has become important to mimic the anatomy of the proximal humerus. Moreover, the difference between the intertubercular groove among different genders could be helpful in forensic medicine.

Keywords: Bicipital groove, greater tubercle, intertubercular groove, lesser tubercle, proximal humerus

Introduction

The bicipital (intertubercular) groove is one of the components of the proximal end of the humerus.[1] It is a slit, that situated on the anterior surface of the proximal humerus, it is limited by greater and lesser tubercles laterally and medially, respectively.[2] Taylor *et al.* divide the bicipital groove into three zones; these zones demarcated according to subscapularis and pectoralis major tendons.[3] Many structures pass through bicipital groove namely; the long head of biceps brachii tendon and a branch from anterior circumflex humeral artery specifically; the ascending branch.[4] Teres major muscle inserted at the crest of lesser tubercle (the medial lip of intertubercular groove)[2] with mean dimension of 187 ± 89 mm; the length was reported to be 49.6 ± 7.9 mm and the width was 7.4 ± 2.5 mm.[5] While latissimus dorsi attached within bicipital groove directly beneath the long head of biceps brachii tendon with a dimension of area was 94 mm.[5] The attachment site of pectoralis major was at the crest of greater tubercle (lateral lip of intertubercular groove).[2]

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The transverse ligament of the humerus did not exist as a separate structure, in all cases, it is mainly subscapularis muscle fibers, that is covered by a fibrous expansion blended with the capsule of the glenohumeral joint, it is overlaying the long head of biceps brachii tendon, it is originated from the posterior lamina of the tendon of pectoralis major muscle.[6] Another study showed that some fibers from supraspinatus muscle and coracohumeral ligament are also participate in the formation of transverse ligament of the humerus.[7]

Regarding the blood supply of the bicipital groove, several studies using different methods, Boesmueller *et al*. used computed tomography angiography and Hufeland *et al*. used

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gross anatomical and histological sections, both of them found that the bicipital groove and its content the long head of biceps brachii tendon supplied by ascending branches of anterior circumflex humeral artery[8,9] while Determe *et al*. conducted anatomical study, it showed that the main blood supply was recurrent branch of brachial artery.[10]

Replication of the normal anatomy is essential to fabricate the best possible prosthetic design. There might be a difference between different sides of the bicipital grooves with regard to depth and width on several studies and a difference between males and females reported by many studies. Starting with Cone *et al*. reported higher correlation obtained from humeral specimens and radiographs, the depth of the bicipital groove in the upper, middle, and lower part of the humeral specimens were 4.3 mm, 8.8 mm, and 5.4 mm, respectively. On the other hand, the measurements obtained from the radiographs were 4.6 mm, 11 mm, and 6.9 mm, respectively. The width of bicipital groove was measured at the top and the middle part.[11]

Several studies differentiate between male and female osteometry of the intertubercular groove, Khan *et al*. reported that the mean depth and width of bicipital groove among males were 7.43 ± 1.29 and 9.18 ± 1.45 mm, respectively. On the other hand, the mean depth and width among females were 7.53 ± 1.24 and 9.05 ± 1.31 mm, respectively. Khan *et al.,* concluded that bicipital groove in female specimens were larger than male specimens in terms of length and depth. Furthermore, more depth was found in the right bicipital groove.[12] The left bicipital groove was longer length and width than the right bicipital groove.[12,13] Hamzehtofigh *et al*., conducted a morphometric study, they used 61 dry adult humeri from Iranian population, significant difference observed between males and females concerning the depth of bicipital groove, they reported that in males the mean was 6.24 ± 0.74 mm, ranging from 4.50–7.50 mm. On the other hand, in females group, the mean was 5.93 ± 0.64 mm, ranging from 4.30–7.50 mm.[14]

Several past studies reported that there was relationship between the anatomy of bicipital groove and the long head of biceps brachii tendon disease.[15] However, a recent study by Ulucakoy *et al*., showed that morphology of bicipital groove is not significantly correlated with the long head of biceps brachii tendon instability instead it is associated with subscapularis rupture as it is part of biceps pulley.[16] Furthermore, Abboud *et al*. announced that no significant relationship existed between depth of bicipital groove and pathology associated with the long head of biceps brachii tendon, the mean depth of the bicipital groove measured on magnetic resonance imaging (MRI) scans was 5.1 ± 1.97 mm, ranging from 2.8 to 6.9 mm.[17]

There is scarcity of literature on the distance between the greater and lesser tubercles that is essential for replication the proximal humerus fractures. This study is conducted to analyze the depth, width of bicipital groove and the distance between the greater and lesser tubercles.

Materials and Methods

Study design

This was a retrospective study designed for patients who attended the orthopedic clinic at Jordan University Hospital, between 2020 and 2021. The study protocol was reviewed and approved by the Institutional review board, Jordan University Hospital (IRB- JUH) (235/2022). The chief complaints for the vast majority of these patients were shoulder pain or trauma.

Inclusion and exclusion criteria

Adult Jordanian cases were involved while cases with bony involvement such as fractures, pathological osseous changes and tumors were excluded.

Three hundred and ten MRI scans for the right and left shoulders were chosen. These images include; 155 for males and the same number for females, 190 right side images in addition 120 left side images. MRI was performed by Ingenia 1.5 T with Omega HP gradient system (Philips, The Netherlands).

Data analysis

IBM statistical package for the social sciences was used, results were showed in the form of mean ± standard error of the mean, maximum and minimum values. Independent *t*-test were used to examine presence of significant difference in the means between male and female at the same side. Furthermore, between the right and left side in same gender. A confidence level used to be 95%. The $P < 0.05$ was considered statically significant. The following parameters were measured namely, depth of the bicipital groove [Figure 1], width of the bicipital groove [Figure 2] and the distance between the tips of greater and lesser tubercles [Figure 3].

Sample size estimation and calculation

This is determined by G* power 3.1.9.7, *t*-test selected with two independent mean differences used (2 groups). The minimum sample size for this test to be used was 176 the power used was 0.95, the effect size was determined to be 0.5. The alpha error probability was 0.05. This study used 310 total MRI, the right side male group was 95 images while the right side female group was 95 images on the other hand 60 images were left side male group and the same for female left side group.

Results

In this study, unpaired 310 MRI scans were used, mean age was 48.79 years ± 0.819. The mean depth of the bicipital groove equals 5.53 ± 0.058 mm, the maximum depth equals 9.18 mm while the minimum equals 2.36 mm. The mean width of bicipital groove equals 7.48 ± 0.92 mm, the maximum width equals 15.89 mm while the minimum equals 3.20 mm. The mean distance between tubercles equals 12.85 ± 0.12 mm, the maximum and minimum distance was 20.23 mm and 7.15 mm, respectively. The mean of depth, width of bicipital groove and the distance between greater and lesser tubercles showed greater in males than females. In

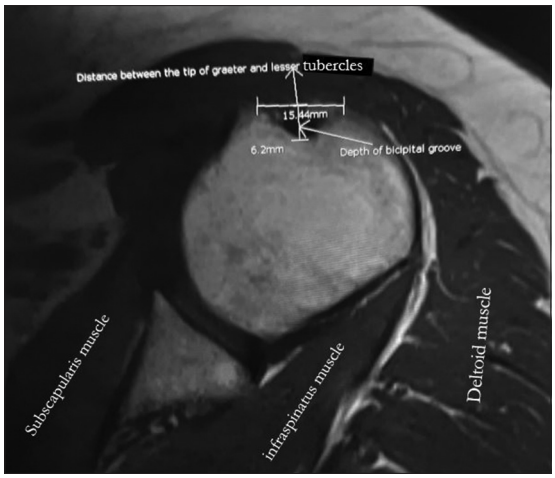

Figure 1: The maximum depth measured for the bicipital groove on the axial section, the line extends from the level of the tip of greater and lesser tubercles to the deepest point of the groove

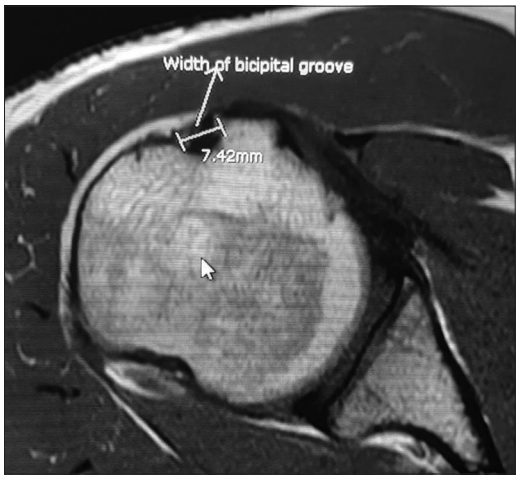

Figure 2: On the axial section, the greater width of bicipital groove was obtained from its middle part between medial and lateral lip at the level of maximum depth of the bicipital groove

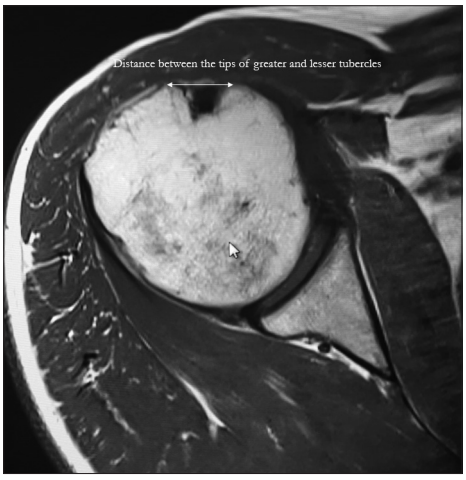

Figure 3: The intertubercular distance was measured from the tip of greater tubercle to the tip of lesser tubercle at the greatest depth of bicipital groove on the axial section

addition, higher depth and width found on the left bicipital groove than the right. Furthermore, longer distance between tubercles found on the left side than the counter side. Box and Whisker plot was used to display the data among different groups [Chart 1].

Table 1 display the descriptive statistics of depth, width of the bicipital groove and the distance between the tip of greater and lesser tubercles among different groups.

This study found significant difference between the males and females with regard to depth and width of bicipital groove and the distance between greater and lesser tubercles. In addition, significant difference in depth between right and left side of bicipital groove was noticed and significant difference in distance between the greater and lesser tubercles between the right and left side was found but there was no significant difference found in width between the two sides of bicipital groove [Table 2].

The mean for whole same males and females as demarking point calculated as average mean values for each sex. The demarking point for the depth and width of intertubercular groove was 5.53 mm and 7.48 mm while the demarking point of the distance between tubercles was 12.85 mm Wilk's lambda showed that these three parameters were less discriminatory tools between males and females [Table 3].

Variation of the bicipital groove morphology

Variation in the anatomy of the bicipital groove exists, this is obvious on the images given in Figure 4a-e. In the present study, hence the morphology data was not recorded in all 310 patients, the percentage of each variations in shape of bicipital groove was not calculated in the present study.

Table 1: Descriptive statistics reported on mean±standard error of mean

	MR	ML	FR	FL
Depth of BG	5.44±0.11	6.21±0.11	5.12±0.10	5.66±0.12
Width of BG	7.65±0.18	7.93±0.16	7.18±0.18	7.23±0.16
Distance between tubercles	12.86±0.23	13.96±0.21	11.96±0.23	13.12±0.24

These measurements in millimeter (mm). BG: Bicipital groove, MR: Male right, ML: Male left, FR: Female right, FL: Female left

Table 2: Comparison of right and left side values between male and female groups after independent *t*-test

	MR versus FR	ML versus FL	MR versus ML	FR versus FL
Depth of BG	0.028*	0.001*	0.000*	0.001*
Width of BG	0.068	0.003*	0.246	0.848
Distance between tubercles	0.005*	0.01*	0.001*	0.001*

*Significant at $P<0.05$. MR: Male right, FR: Female right, ML: Male left, FL: Female left

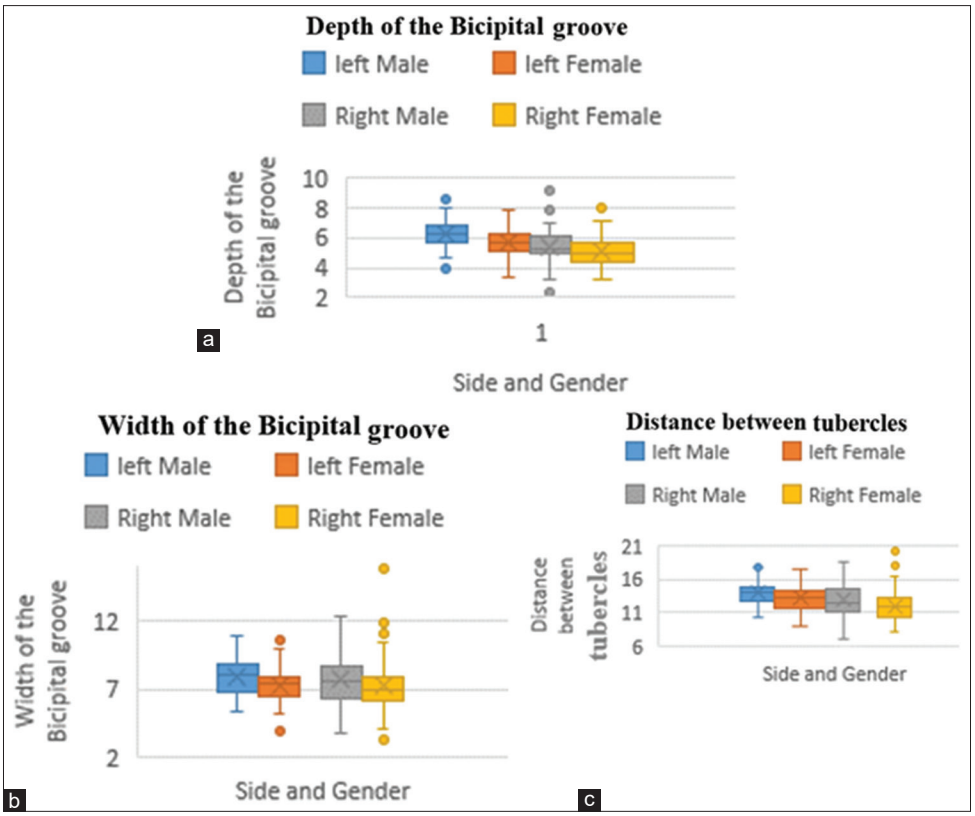

Chart 1: (a) Box and whisker plot to display the difference in depth of bicipital groove among four groups. (b) Box and whisker plot to display the difference in width of bicipital groove among four groups. (c) Box and whisker plot to display the difference in distance between the tips of greater and lesser tubercles among four groups

Table 3: The demarking points to measure the depth, width and distance between greater and lesser tubercle

Parameter	Mean female	Mean male	Demarking point	SDR	Wilk's lambda	*F*-ratio	Significant
Depth of BG	5.33	5.74	Female <5.53<male	107.71	0.96	12.828	0.00
Width of BG	7.20	7.76	Female <7.48<male	107.81	0.970	9.673	0.002
Distance between tubercles	12.41	13.29	Female <12.85<male	107.10	0.958	13.569	0.00

BG: Bicipital groove, SDR: Sexual dimorphism ratio

Discussion

Reproduction of the best possible biomechanics of the shoulder joint is the goal, this study helps to achieve this goal by providing the accurate measurement for Jordanian population; as it differs among various population. Several orthopedic procedures and reconstruction surgeries require a solid knowledge regarding the morphometry of the proximal humerus.

This study showed that there was common anatomical variation which exist at the proximal humerus. Significant gender differences found in terms of several measurements in addition among the right and left side, of these parameters were depth and width of the bicipital groove, this study showed that the mean depth and width for right side bicipital groove were 5.28 ± 1.01 mm and 7.42 ± 1.79 mm while for left bicipital groove were 5.94 ± 0.92mm and 7.58 ± 1.29 mm, respectively. The population with less depth of bicipital groove than this study was considered shallower while populations with greater width than this study was considered wider. Several populations had shallower and Wider bicipital groove than Jordanian population such as Indian,[18-21] Western Bengal,[22] Ethiopian[23] while other population had deeper and wider bicipital groove such as South Indian[24] and South African.[12] On the other hand, other populations had similar results to Jordanian population including; North Indian.[25]

Different study by Rajan and Kumar showed that shallower and narrower bicipital groove on South Indian population.[13] In addition, Karmali and Modi reported that on Eastern Indian population.[26] The morphometric study of the bicipital groove was reported to be associated with different pathological conditions; shallow groove has been illustrated to be linked with subluxation or dislocation of biceps tendon.[4,11] As well as, chronic trauma as a result of impingement by acromion or rotator cuff muscles.[27] Moreover, narrow groove has been found to be associated with persistent stress that leads to attritional frictional changes.[28,29]

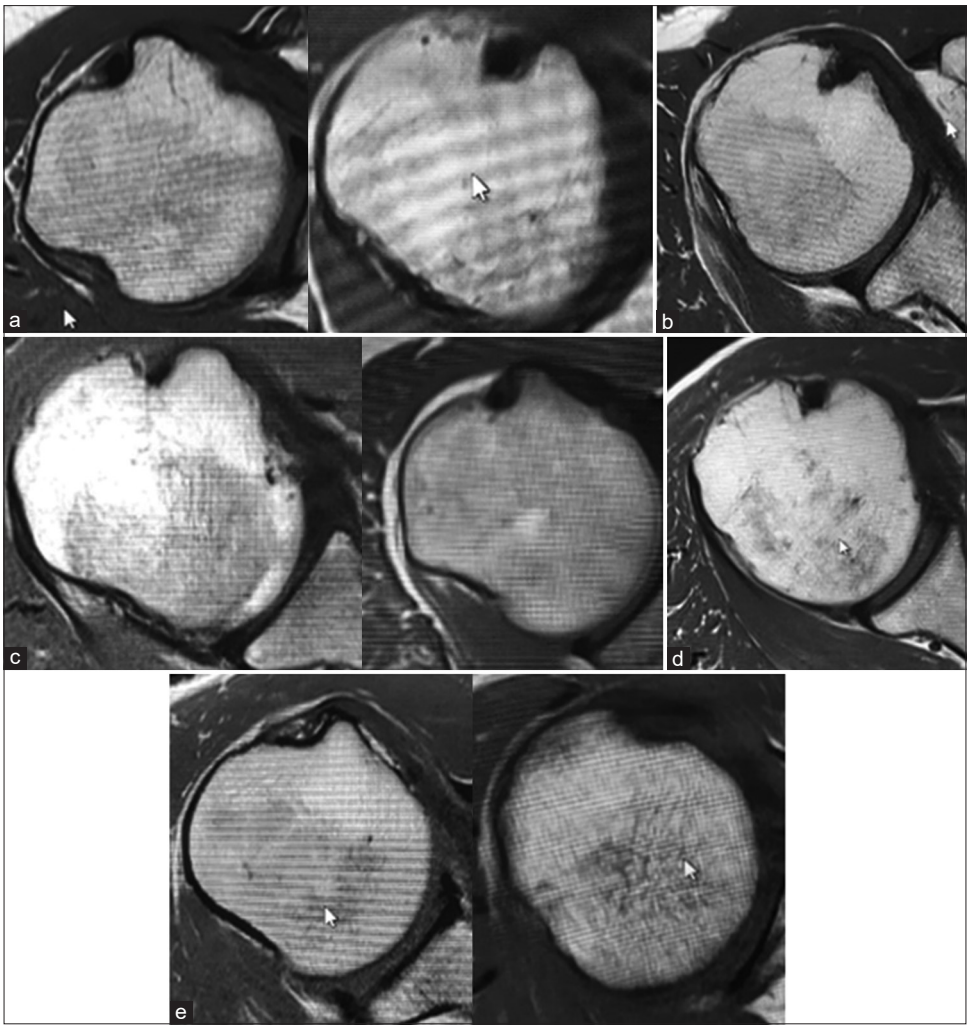

Figure 4: Variation on the shapes of the bicipital groove. (a) Deep and wide, (b) Mean depth and width, (c) Deep and narrow, (d) Deep and mean width, (e) Wide and shallow

Depth of the bicipital groove

Significance right–left side differences existed on several studies, part of these were similar to present study, they found that the mean depth of left side is more than right side including; Goshu,[23] Rajan and Kumar,[13] Rajani and Man,[25] Arunkumar *et al*.,[30] and Karmali and Modi[26] while Gupta *et al*.,[20] Ghalawat *et al*. found no significance difference with increased depth of left bicipital groove in comparison with the right bicipital groove.[31] conversely, the depth of right side bicipital groove was more than the left on studies by Srimani *et al*.[22] and Khan *et al*.[12] and Ashwini and Venkateshu[24] but Murlimanju *et al*.,[19] Venkatesan *et al*. found no significance difference with deeper right side bicipital groove than the left one.[21] Moreover, Vettivel *et al*., found almost the same depth for both sides bicipital groove.[18] Significance difference existed in terms of the depth of bicipital groove between males and females with deeper bicipital groove on males, this was reported by Kaur and Gupta.[32]

Width of bicipital groove

This study did not report significance difference in width between the right and left sides bicipital groove but wider bicipital groove reported on the left side, Murlimanju *et al*.[19] and Khan *et al*.[12] was consistence with this result. Furthermore, Rajan and Kumar[13] and Karmali and Modi[26] found significance difference in width with wider left side bicipital groove but the same width reported by Rajani and Man.[25] However, Vettiivel *et al*.[18] and Ghalawat *et al*.,[31] Srimani *et al*.[22] and Goshu[23] found significance difference with increased width of the right bicipital groove. Furthermore, Arunkumar *et al*.,[30] Ashwini and Venkateshu[24] and Venkatesan *et al*.,[21] Gupta *et al*.,[20] and Kaur and Gupta[32] found wider right side bicipital groove but no significance difference existed.

The bicipital groove width at the top of intertubercular groove was higher than the measured width at the middle of the groove. This reported by Cone *et al*.[11] and Kuar and Gupta[32] while Kishve *et al*.[33] found that the deepest part of intertubercular groove existed at the middle. Table 4 summarizes the findings related to width and depth of bicipital groove among different population.

Table 4: Comparison of depth and width of bicipital groove in right and left side with previous studies data

Author	Year	Population	Materials	Depth of BG (mm)		Width of BG (mm)	
				Right	Left	Right	Left
Levinsohn and Santelli[34]	1991		55 radiographic x-ray	5		7	
Vettivel *et al*.[18]	1992	Indian	200 humeri	3.72	3.70	10.23*	9.8*
Ueberham and Le Floch-Prigent[35]	1998		100 humeri	2.44		6.33	
Ward *et al*.[36]	2006		38 MRI and CT scans	4.69±1.94		15.7	
Wafae *et al*.[37]	2010		50 humeri	4.0		10.1	
Abboud *et al*.[17]	2010		75 MRI scans	5.1			
Murlimanju *et al*.[19]	2012	Indian	104 humeri	4.7±2	4.2±1.6	8.3±2.4	8.7±2.2
Rajani and Man[25]	2013	North Indian	101 humeri	5±1	6±1	8±2	8±2
Gupta *et al*.[20]	2015	North Indian	100 humeri	4.3±1.1	4.1±0.8	7.4±1.66	8.6±1.6
Rajan and Kumar[13]	2016	South Indian	100 humeri	4.21*±0.58	5.01*±1.05	6.84*±1.01	7.74*±1.96
Srimani *et al*.[22]	2016	Western Bengal	170 humeri	4.63*±0.38	4.45*±0.3	8.42*±0.85	7.7*±0.5
Arunkumar *et al*.[30]	2016	South Indian	98 humeri	5±1	6±1	8.7±1	8.3±4
Venkatesan *et al*.[21]	2017	South Indian	200 humeri	4.65±1.04	4.55±1.146	9.12±1.37	8.86±1.65
Ashwini and Venkateshu[24]	2017	South Indian	87 humeri	6.48±1.13	6.14±1.04	8.53±1.56	7.96±1.39
Goshu[23]	2019	Ethiopian	51 humeri	4.64*±0.08	4.83*±0.07	8.36*±0.1	8.32*±0.08
Karmali and Modi[26]	2019	Eastern India	86 humeri	4.17±0.56	5.01±1.02	6.79±0.53	7.56±1.05
Khan *et al*.[12]	2020	South African	160 humeri	7.73*±1.31	7.2*±1.18	8.98	9.27
Ghalawat *et al*.[31]	2020	North Indian	50 humeri	3.71±0.71	3.82±0.65	13.03*±1.46	12.02*±1.75

*Significant. BG: Bicipital groove, CT: Computed tomography, MRI: Magnetic resonance imaging

Distance between the greater and lesser tubercles

This parameter allows the orthopedic surgeon to predict the distance between tubercles that is essential to produce the best possible result after treating proximal humeral fractures. This study showed that significance difference between males and females in terms of the distance between the greater and lesser tubercles with longer distance in males. Furthermore, significant difference reported between right and left sides with longer distance on the left side. The previous study values are not available to compare with the present study result.

Limitations of the study

If the sample size is greater for each age group, then the chronological changes for the bicipital groove can be studied in relation to long head of biceps brachii tendon pathology. In addition to that if we know the dominant hand of patient, the relation of using the hand to the different side morphometry of the bicipital groove can be studied.

Conclusion

This study reported significant results between genders in terms of the depth and width of the bicipital groove and the distance between greater and lesser tubercles. In addition, a significant difference found between right and left sides humeri in terms of depth of bicipital groove and the distance between greater and lesser tubercles was found. The depth, width of bicipital groove and the distance between the greater and lesser tubercles were longer in males than females and in left side than the right. There is no significance in the width, with wider left side bicipital groove. These results will be helpful for orthopedic surgeon to restore fractures of the proximal end of humerus in the best possible way.

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Conflicts of interest

There are no conflicts of interest.

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