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Morphometric Analysis of Clavicle: A Multi-Detector Computed Tomography Study

Nayeem Ahmad Sheikh[1*], Mohammad Umar Zakee[2], Amit Bisht[3]

[1*,2]M.Sc. Research fellow, Department of Radiological and Imaging Techniques, College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, 244001.

[3]Assistant professor, Department of Radiological and Imaging Techniques, College of Paramedical Sciences, Teerthanker Mahaveer University, Moradabad, Moradabad, Uttar Pradesh, India, 244001.

***Corresponding Author:**

Nayeem Ahmad Shiekh

Department of Radiological and Imaging Techniques Repora, Lar Ganderbal, Jammu & Kashmir, 191131.

Email ID: nayeemahmadsheikh09@gmail.com

ORCID-ID 0009-0005-1088-510X

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ABSTRACT

The clavicle, a critical component of the shoulder girdle, plays a vital role in upper limb mobility and structural integrity. Its morphometry dimensions have significant clinical implications, particularly in orthopedic surgery, trauma management, and implant design. This study aims to analyse the morphometric characteristics of the clavicle using multi-detector computed tomography (CT) imaging. A total of 120 clavicles from a diverse adult population were evaluated using multi-detector CT scans. Measurements included clavicular length, width and depth of curvature at different segments. The study also assessed variations based on laterality (right vs. left) and gender differences. Preliminary findings indicate considerable individual and demographic variability in clavicular morphometry. Male clavicles exhibited greater dimensions than female counterparts, and significant asymmetry was observed between the right and left clavicles. Understanding these morphometric variations is crucial for optimizing surgical procedures such as intramedullary nailing and fracture fixation. This study provides a comprehensive database on clavicular morphometry, aiding orthopedic surgeons in preoperative planning and implant customization. The findings also contribute to forensic anthropology, prosthetic development, and biomechanical modelling. Future research may explore population-specific variations and the impact of age-related changes on clavicular structure.

Keywords: *Clavicle, Morphometric Analysis, Computed Tomography, Orthopedic Surgery, Intramedullary Nailing.*

1. INTRODUCTION

The clavicle is a long bone that means "small key" in Latin. It gives the shoulder support so that the arm can swing freely away from the trunk. The clavicle transfers the limb's weight to the sternum. The lateral and medial ends of the bone, as well as the shaft, are cylindrical structures.(1) They Connecting the axial skeleton to the pectoral girdle, this bone is a vital component of the skeletal system, facilitating daily functional movement. The clavicle is the body's first ossified bone. It ossifies in membrane except for its medial end. It ossifies from one secondary center and two primary centers.(2) About the 45th day of intrauterine life, the two main centers fuse together after appearing in the shaft between the fifth and sixth weeks. The medial end secondary center develops over the course of 1.5–17 years and merges with the shaft over the course of 21–22 years. A secondary center for the acromial end may occasionally exist. The following characters indicate which side of the body a clavicle belongs to:

a. The medial end is broad and quadrilateral, the lateral end is smooth.

b. The shaft has a modest curvature, with its medial two-thirds convex and its lateral one-third concave.

c. The central one-third of the inferior surface has a longitudinal ridge.(3)

There are two halves to the shaft: the medial two-thirds and the lateral one-third. The lateral portion of the shaft is compressed downward from above. The margins of it are anterior and posterior. The front edge has a forward concavity. The rear border of the posterior region is convex. There are two surfaces on this portion of the bone: superior and inferior. The inferior surface has a ridge known as the trapezoid ridge and an elevation known as the conoid (Greek cone) tubercle.

The superior surface is subcutaneous. There are four surfaces and a circular shape in the medial two-thirds of the shaft. Forward convexity characterizes the anterior surface. Smoothness is present on the posterior surface.(4) The middle portion of the superior surface is rough. At the medial end of the inferior surface is an impression of an oval that is rough. This surface has a longitudinal subclavian groove on its lateral half. The lateral end of the groove contains the nutritional foramen.(5) The shoulder's lateral, or acromial (Greek for "peak") end is flattened downward from above. It has a facet that joins the scapula's acromion process to form the acromioclavicular joint. The sternoclavicular joint is formed by the articulated clavicular notch of the manubrium sterni and the quadrangular medial or sternal end. The inferior aspect is where the articular surface meets the first costal cartilage during articulation. There are just two planar diarthrosis articulations because of the anatomy of the clavicle. A "double plane joint" is another name for this kind of articulation, in which two joint chambers are divided by a layer of articular cartilage.(6)

The acromial end of the clavicle and the acromion of the scapula, respectively, create the acromioclavicular joint, which is the first. It allows for a small amount of glide around the shoulder area. A capsule of articular cartilage containing intra-articular synovium envelops the synovial joint. The scapula acromion and the clavicle are strongly connected by the acromioclavicular ligament, which limits movement around the clavicle at its acromial end. The sternoclavicular joint, which is made up of the sternum's manubrium and the clavicle's sternal end, is the other. Because it secures the scapula and clavicle to the axial skeleton, this synovial joint is crucial. Ligaments supporting the sternoclavicular joint stabilize the joint on both its anterior and posterior surfaces.(7) Additionally, two auxiliary ligaments support the joint: **A**anterior interclavicular ligament- It protects the joint's superior surface and keeps the clavicle from dislocating when the shoulder is lowered. Posterior costoclavicular ligament, which extends from the clavicle costal tuberosity to the superior and medial surfaces of the first rib, keeps the clavicle from dislocating when the shoulder elevated.

The clavicle's ends—the round, pyramid-shaped sternal end, known as the medial two-thirds—and its broad, flat acromial end, known as the lateral third, are indicative of its orientation. Depending on whether the superior or inferior surface of the bone is being viewed, each end has different bony markers.(8) The clavicle's superior surface appears to be smooth. There are numerous conspicuous lines and a rough inferior surface of the clavicle that show potential attachment points for muscles and ligaments. This study aims to find out the morphometric parameters of the clavicle & to figure out the clavicle structural characteristics in the Western population of UP.

2. MATERIALS AND METHODS

The CT scans used in this investigation were obtained using conventional procedure from the radiology department database of Teerthankar Mahaveer Hospital and Research Centre, College of Paramedical Sciences, Moradabad, Uttar Pradesh. The PACS radiology system was used to identify patients who underwent thoracic CT imaging as part of their diagnostic workup for unrelated conditions. The United Imaging uCT 780, 160 slice was used to do the CT thorax. Osirex was used to store the data. The CT thorax investigations that included both clavicles' whole length were chosen. Images were examined in the bone window and a 3-D reconstruction of the clavicle was completed. Axial, coronal, and sagittal clavicles were orientated, and measurements were taken. A total of sixty participants were enrolled in the trial.

Inclusion Criteria

1. CT thorax showing both clavicles' whole length in adults over the age of 18.

Exclusion Criteria

1. Clavicle malformation that is congenital.
2. A prior clavicle operation.
3. Clavicle fracture in the past.

By connecting the centre points along the clavicle's length between two articular surfaces, the length (L) of the clavicle (9) was determined **(Fig. 1A)**. The clavicle's width in the axial plane (9) was determined by drawing a line from a point on its anterior surface to a point on its posterior surface, measuring the distance between the two points, and defining the clavicle's width as the smallest width (Wsm), sternal end (Ws), and acromial end (Wa) (9) **(Fig. 1B)**.

Two lines were drawn: one from the anterior point of the lateral end to the apex of the anterior edge of the medial curvature, and one from the most posterior point of the medial end to the apex of the posterior edge of the lateral curvature. The depth of curvature of medial/sternal curvature (Ds) and lateral/acromial curvature (Da), respectively, was defined as the distance measured perpendicularly from the apex of the posterior edge of medial curvature and the apex of the anterior edge of lateral curvature to these lines **(Fig. 1C)**.

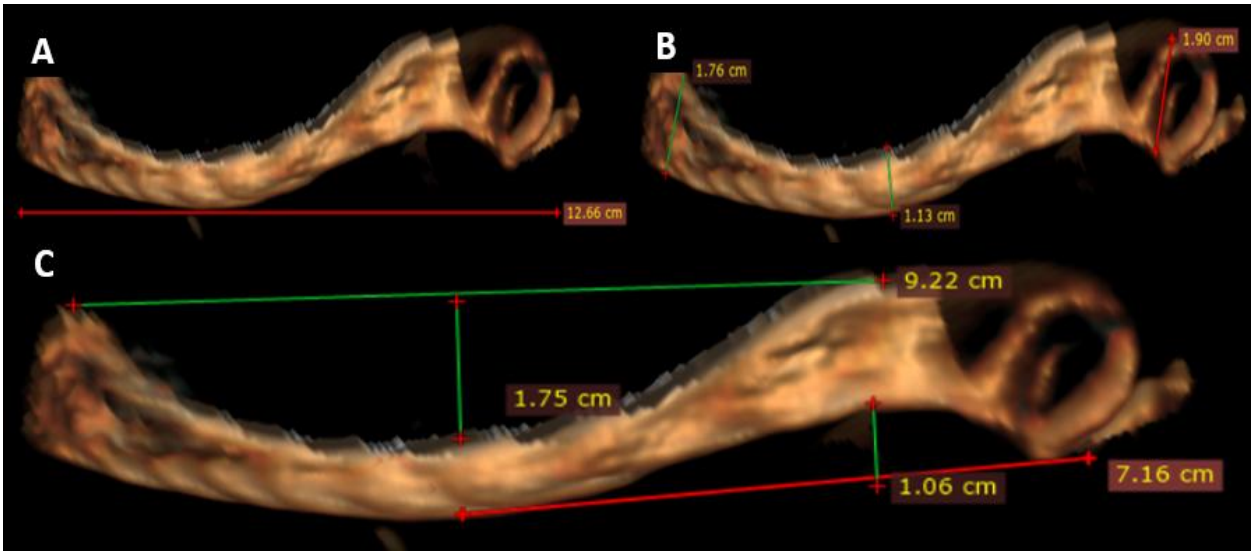

Fig-1 Clavicle is measured using these parameters. (A) Length of clavicle; (B) Width at acromial end, width at sternal end, smallest width; (C) Depth of curvature at acromial end & at sternal end.

Statistical Analysis

The collected data were summarized by using the Descriptive Statistics: frequency, percentage; mean and S.D. The Paired "t" test was used to compare the CL, WS, WA, WSM, DA, and DS; between right and left sides. The Independent sample "t" test was used to compare the morphometric parameters of the clavicle according to gender. The One-way ANOVA was used to compare the morphometric parameters of the clavicle according to age groups. The Post hoc analysis, Tukey test was used for the multiple comparisons. The Pearson correlation coefficient: ("r") was used to find the relation between the various morphometric parameters of the clavicle. The p value < 0.05 was considered as significant. Data were analyzed by using the SPSS software (SPSS Inc.; Chicago, IL) version 29.0.10.

3. RESULTS

A total of sixty patients—36 men and 24 women—had twenty clavicles examined.

1. Length: The individuals under study had a clavicle length of (134.37 ± 13.00) mm on average. There was a significant 7.35 mm difference in clavicles between males and females (P = 0.009). The average length of the left and right clavicles was (136.57 ± 11.72) mm and (137.24 ± 10.76) mm, respectively.

2. Width: The sternal end (Ws), acromial end (Wa), and middle of the clavicle (Wsm) of male clavicles were wider than those of females.

3. Depth of Curvature: Males had larger average depths of curvatures than females at both ends, and this difference was statistically significant at both ends (P = 0.023 and P = 0.013).

Table 1 displays the morphometric parameters of OC together with their mean values and standard deviations. **Table 2** lists the morphometric parameters and demographic information of the study population categorised by age.

Table-1: Results of morphometric measurements on occipital condyles in study population.

		Mean	S.D.	"t"	p value
CL (R) mm	Male	140.81	10.72	3.42	0.001*
	Female	131.89	8.50		
CL (L) mm	Male	140.15	11.24	3.10	0.003*
	Female	131.20	10.47		
CL (T) mm	Male	139.97	10.65	2.72	0.009*
	Female	132.62	9.87		

WS (R) mm	Male	20.34	3.40	2.55	0.014*
	Female	18.38	1.95		
WS (L) mm	Male	19.96	2.85	2.60	0.012*
	Female	18.20	2.03		
WS (T) mm	Male	20.14	2.80	2.66	0.010*
	Female	18.43	1.88		
WA (R) mm	Male	19.14	3.23	2.36	0.022*
	Female	17.17	3.10		
WA (L) mm	Male	19.58	3.40	2.08	0.042*
	Female	17.81	3.00		
WA (T) mm	Male	19.37	3.08	2.37	0.021*
	Female	17.56	2.67		
WSM (R) mm	Male	13.74	1.74	4.38	< 0.001*
	Female	11.73	1.75		
WSM (L) mm	Male	13.37	1.76	3.67	0.001*
	Female	11.70	1.69		
WSM (T) mm	Male	13.37	1.65	3.03	0.004*
	Female	12.05	1.70		
DA (R) mm	Male	12.91	2.89	2.57	0.013*
	Female	11.17	2.02		
DA (T) mm	Male	12.26	2.51	2.23	0.023*
	Female	11.07	2.17		
DA (L) mm	Male	11.52	2.84	-2.58	0.013*
	Female	13.80	4.00		
DS (R) mm	Male	13.88	3.30	2.52	0.015*
	Female	11.69	3.30		
DS (L) mm	Male	14.58	3.12	2.40	0.020*
	Female	12.40	3.89		
DS (T) mm	Male	14.17	2.88	2.56	0.013*
	Female	12.21	2.94		

R right, L left, T total, SD standard deviation, CL clavicle length, Ws clavicle width at sternal end, Wa clavicle width at acromial end, Wsm clavicle width at smallest end, Da depth of curvature at acromial end, Ds depth of curvature at sternal end.

Table 2: Results of morphometric measurements on occipital condyles in study population stratified according to age.

		Mean	S.D.	"F"	p value
CL (R) mm	18-20	125.73	12.38	3.89	0.004*
	21-30	137.54	6.98		
	31-40	141.68	7.66		
	41-50	134.88	13.36		
	51-60	138.61	9.98		
	61-70	151.33	5.23		
CL (L) mm	18-20	126.30	11.79	3.78	0.005*
	21-30	136.65	7.65		
	31-40	144.35	8.78		
	41-50	133.85	13.03		
	51-60	140.27	12.66		
	61-70	150.55	7.03		
CL (T) mm	18-20	126.01	10.37	4.26	0.002*
	21-30	137.10	7.20		
	31-40	143.01	7.81		
	41-50	134.37	13.00		
	51-60	139.44	10.39		
	61-70	150.94	6.06		
WS (R) mm	18-20	25.68	2.20	6.38	< 0.001*
	21-30	18.41	3.49		
	31-40	21.11	4.01		
	41-50	19.28	3.77		
	51-60	19.04	2.02		
	61-70	21.10	2.54		
WS (L) mm	18-20	26.15	3.15	8.77	< 0.001*
	21-30	17.70	1.76		
	31-40	19.84	4.19		
	41-50	19.07	3.17		
	51-60	19.32	2.48		
	61-70	19.28	2.41		
WS (T) mm	18-20	25.91	1.30	10.45	< 0.001*
	21-30	18.08	1.43		
	31-40	20.49	3.52		
	41-50	19.21	3.33		

	51-60	19.20	2.07		
	61-70	20.20	2.31		
WA (R) mm	18-20	14.58	4.46	2.64	0.033*
	21-30	20.79	5.01		
	31-40	21.56	5.67		
	41-50	18.53	3.82		
	51-60	18.23	4.05		
	61-70	19.83	2.06		
WA (L) mm	18-20	24.80	2.74	3.95	0.004*
	21-30	21.74	4.59		
	31-40	17.39	3.83		
	41-50	19.26	3.48		
	51-60	18.84	4.45		
	61-70	20.10	2.61		
WA (T) mm	18-20	19.69	2.04	2.56	0.044*
	21-30	21.27	2.53		
	31-40	19.48	2.71		
	41-50	18.90	3.40		
	51-60	18.53	4.11		
	61-70	19.96	2.09		
WSM (R) mm	18-20	13.19	2.34	2.51	0.041*
	21-30	12.70	1.44		
	31-40	14.81	1.06		
	41-50	11.96	1.90		
	51-60	12.83	1.95		
	61-70	13.33	2.70		
WSM (L) mm	18-20	11.96	1.89	2.50	0.042*
	21-30	12.92	1.35		
	31-40	14.44	1.52		
	41-50	12.10	1.94		
	51-60	12.94	1.59		
	61-70	11.59	3.09		
WSM (T) mm	18-20	12.57	1.77	2.62	0.034*
	21-30	12.81	1.28		
	31-40	14.63	0.86		
	41-50	12.03	1.81		

	51-60	12.89	1.64		
	61-70	12.46	2.89		
DA (R) mm	18-20	15.26	3.10	2.75	0.028*
	21-30	13.36	1.70		
	31-40	11.79	1.43		
	41-50	12.40	3.28		
	51-60	11.56	2.36		
	61-70	11.83	1.34		
DA (L) mm	18-20	17.69	5.02	3.59	0.007*
	21-30	14.52	3.88		
	31-40	12.07	1.43		
	41-50	11.65	4.08		
	51-60	12.88	3.54		
	61-70	16.00	2.23		
DA (T) mm	18-20	16.48	2.68	5.43	< 0.001*
	21-30	13.94	1.96		
	31-40	11.93	1.28		
	41-50	12.02	2.98		
	51-60	12.22	2.03		
	61-70	13.91	0.71		
DS (R) mm	18-20	19.96	4.35	4.24	0.003*
	21-30	14.80	4.87		
	31-40	12.35	3.70		
	41-50	13.05	4.40		
	51-60	13.68	3.56		
	61-70	11.33	1.72		
DS (L) mm	18-20	21.06	4.31	5.01	0.001*
	21-30	14.28	2.63		
	31-40	13.53	4.00		
	41-50	14.15	3.37		
	51-60	13.18	4.81		
	61-70	12.85	4.13		
DS (T) mm	18-20	20.51	3.98	5.79	< 0.001*
	21-30	14.54	3.60		
	31-40	12.94	3.56		
	41-50	13.60	3.49		

	51-60	13.43	3.56		
	61-70	12.09	1.72		

R right, L left, T total, SD standard deviation, CL clavicle length, Ws clavicle width at sternal end, Wa clavicle width at acromial end, Wsm clavicle width at smallest end, Da depth of curvature at acromial end, Ds depth of curvature at sternal end.

4. DISCUSSION

Conventionally, conservative techniques have been used to treat clavicle shaft fractures. Two popular surgical methods for treating displaced clavicle shaft fractures are plating and intramedullary fixation. A better surgical technique and gadget will be designed with the use of morphometric data of the clavicle and its medullary canal. **Shiddanna M. Patted et al.** (9) measured the clavicle's length from sternal to acromial, its width at the acromial and sternal ends, and its narrowest width, as well as the depth of curvature at both ends. The mean clavicle dimensions: length, width at acromial end, sternal end & the smallest width were 142.5±12.2 mm, 20.7±3.0 mm, , 23.5±3.7 mm and 11.5±1.4 mm respectively. The clavicle's acromial and sternal ends had depths of curvature of 11.1±2.9 mm and 17.7±2.9 mm. Male clavicles were 14.2 mm longer than female clavicles, a significant difference (P=0.000). It was discovered that male clavicles were significantly wider in the middle (Wsm) than female clavicles (P=0.00).Males had greater average depths of curvatures than females at both ends, and the medial curvature was statistically significant but the lateral curvature was not (P=0.000 and P=0.3). **Praveen Kumar Panuganti et al.** (10) determined that the clavicle's length, width at acromial end, sternal end & the smallest width were 142.5±1.1 mm, 22.1±0.8 mm, 19.7±1.1 mm, 11.45±0.6 9 mm. The clavicle's acromial and sternal ends had depths of curvature are 22.3±0.8 mm and 10.6±0.8 mm. **Jonas Andermahr et al.** (11) The average length, width at acromial end, sternal end & the smallest width of clavicle were found to be 151±11 mm, 22±4 mm, 25±4 mm & 12 ±2 mm. The clavicle's acromial and sternal ends had depths of curvature are 12±3 mm and 17±3 mm. **P. R. King et al.** (12) It was determined that the clavicle's average length, width at acromial end, sternal end & the smallest width of clavicle were found to be 156.8±9.7 mm, 18.2±3.0 mm,14.5±2.2 mm & 12.7±1.7 mm.

Our study's findings indicate that the CL, W_a, Ws, Wsm, Da, Ds in the clavicle of adults are 136.9±10.2 mm, 18.4±2.8 mm, 19.2±2.3 mm, 12.7±1.6 mm, 11.6±2.3 mm & 13.1±2.9 mm. The sternal end (Ws), acromial end (Wa), and middle of the clavicle (Wsm) of male clavicles were wider than those of females. Depth of Curvature: Males had larger average depths of curvatures than females at both ends, and this difference was statistically significant at both ends (P = 0.023 and P = 0.013).

Table 3: Comparison of clavicle measurements of current study with other studies.

AUTHOR	CL	WA	WS	WSM	DA	DS
Shiddanna M. Patted et al. (9)	142.5±12.2 mm,	20.7±3.0 mm	23.5±3.7 mm	11.5±1.4 mm	11.1±2.9 mm	17.7±2.9 mm
Praveen Kumar Panuganti et al. (10)	151±11 mm	22±4 mm	25±4 mm	12 ±2 mm	22.3±0.8 mm	10.6±0.8 mm
Jonas Andermahr et al. (11)	22.91±3.16 mm	10.85±1.25 mm	9.1±1.6 mm	5.0±1.3 mm	12±3 mm	17±3 mm
P. R. King et al. (12)	156.8±9.7 mm	18.2±3.0 mm	14.5±2.2 mm	12.7±1.7 mm	-	-
Our Study	136.9±10.2 mm	18.4±2.8 mm	19.2±2.3 mm	12.7±1.6 mm	11.6±2.3 mm	13.1±2.9 mm

5. CONCLUSION

This study provides the morphometric features of the clavicle of the studied population. The individuals under study had a clavicle length of (134.37 ± 13.00) mm on average. There was a significant 7.35 mm difference in clavicles between males and females. The average length of the left and right clavicles was (136.57 ± 11.72) mm and (137.24 ± 10.76) mm, respectively. The sternal end (Ws), acromial end (Wa), and middle of the clavicle (Wsm) of male clavicles were wider than those of females. Males had larger average depths of curvatures than females at both ends, and this difference was statistically significant at both ends. For orthopaedic surgeons, anthropologists, and anatomists, the measurements of the

clavicles are useful for surgery. The data describing the morphometric parameter of the clavicle are lacking in our population and a CT based study in this regard is needed.

6. LIMITATION

- We have discussed a few of this study's drawbacks. First off, we did not evaluate the clavicle based on BMI in this study, which may possibly be a variable for future research.
- The second choice, which can provide different findings, is to utilise a large sample size.
- Participants who are older than 70 and those under the age of 18 could be included for further study.
- Because there are fewer female applicants than male candidates in this study, changing this ratio may affect the results in different ways.

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