ORIGINAL ARTICLE

Morphometric Study of the Clavicle in Normal Adult Shoulders in East Java, Indonesia: A 3D Computed Tomography Analysis

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ABSTRACT

Introduction: Clavicle plate should be well measured in its production process, since size mismatch often leads to complications like implant prominence, screw loosening, and malunion. The study aims to investigate the clavicle morphometry of adults in Indonesia to aid in preventing complications caused by mismatch of clavicle plates for the better treatment of clavicle fractures. **Materials and methods:** This retrospective study investigates clavicle morphometry in normal adult subjects from East Java through a comprehensive analysis of 3D computed tomography (CT) scans collected between July 2022 and June 2023. The Radiant Dicom application facilitated precise morphometric measurements. Sample size determination followed Slovin's formula to ensure representativeness of the East Java population. Age and gender data were recorded for each subject. Statistical analysis, conducted using SPSS version 25, involved ANOVA or independent t-test comparisons of morphometric parameters across gender and age groups. **Results:** In this study, a total of 385 patients were selected through simple random sampling, meeting the specified inclusion and exclusion criteria. Further analysis indicated that female clavicles were significantly shorter than male clavicles. Age and gender was significantly correlated with the superior view morphology of the clavicle ($p = 0.005$), but not in frontal view. **Conclusion:** This finding indicates that age and gender significantly correlate with the morphometric parameters of the clavicle. Therefore, the use of clavicle plates must take into account the patient's age and gender. The morphometric results of patients in East Java among adult was shorter which is differs from several other countries.
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Keywords: Clavicle, Shoulder, Morphometry, Clavicle plating, 3D Computed tomography scan

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INTRODUCTION

Collarbone (clavicle) fractures are fractures of the shoulder region in the upper extremity and one of the most common fractures seen in emergency rooms. About 2,6 – 4 % of all adult fractures are clavicle fractures and the peak incidence occurs in children and young adults.(1) The majority of clavicle fractures occur at the midshaft accounting for approximately 80% of all clavicle fractures, followed by distal clavicle and medial clavicle fractures. Clavicle fracture treatment trends tend to shift from conservative to operative treatment.(2) Initially, clavicle fractures are treated non-operatively; however, Yan M.Z et.al reported in their systematic review that surgical intervention specifically clavicle plate insertion was associated with better clinical outcomes compared to non-surgical approaches for midshaft clavicle fractures. Surgical treatment as the optimal treatment for clavicle fractures also became a trend after the results of The Canadian Orthopaedic Trauma Society (COTS) study were released which showed the surgically treated group with superior plates showed lower nonunion rates and faster union times.(3)

The most common surgical treatment for clavicle fractures is Open Reduction Internal Fixation (ORIF). The use of Plate and screw is considered the gold standard surgical option. (4) Plate and screw fixation provides rigid fixation with cortical compression and rotational control. Several Randomized clinical trial (RCT) studies have reported lower nonunion rates compared to nonoperative treatment ranging from 0% to 2.8% when using plate and screw fixation (5). Locking plates are also used in minimally invasive percutaneous plate osteosynthesis (MIPO). By avoiding periosteal stripping with soft tissue preservation, locking plates with the MIPO technique in clavicle fractures has reported rapid union. (6)

Malunion fracture of clavicle in Indonesia occured mostly due to the mismatch of the plate dimension and the morphology of the bone. (7) Thus the morphometry of clavicle, measured from samples from adult Indonesian patients, is among the early step to reduce malunion incident related to plate choices does not fit the anatomical structure.

MATERIALS AND METHODS

This study was a retrospective study conducted with an analytic design taking data retrospectively or backward. The study was approved by the Health and Research Ethical Committee of Dr. Soetomo General Hospital (reference 14/SC/1333). The population of this study was all adult patients who had undergone CT SCAN Thorax examination at Dr. Soetomo General Hospital from July 2022 to June 2023. The number of samples to be taken is 385 samples with a simple random sampling technique. Inclusion Criteria: 1) Patients with a history of having performed CT SCAN Thorax, aged more than 17 years. 2) Patients with a history of having performed CT SCAN Thorax without any trauma to the shoulder performed CT-SCAN. 3) Patients with a history of performing CT SCAN Thorax without a previous operative history Exclusion criterion of patients as follows: 1) Patients with a history of injury to the CT SCAN shoulder, 2) Patients with a history of surgery on the CT-SCAN shoulder, and 3) A picture of incomplete clavicula on CT-SCAN Thorax.

The independent variables in this study were patients with a history of CT SCAN at Dr. Soetomo General Hospital who were then recorded for age, gender, diagnosis, and date and year of treatment. The dependent variable assessed in this study was patients with a history of CT SCAN use without complaints on the shoulder performed. Patient characteristics were measured with numerical and ordinal data scales, while Geometry data of clavicle bone morphology from the top and front were measured on a numerical scale.

Data collection was carried out in the radiology installation by patients medical records who have performed CT SCAN Thorax actions but without a history of trauma, then from the data the patient is recorded in the medical record, and then the patient's CT-SCAN CD will be collected for sample, after that the CT SCAN image results are used to measure morphometry of the humeral bone using the Radiant Dicom application for length measurement (Figure 1), and with goniometry for angle measurement and radius of the circle (diameter) and then the data results will be processed in SPSS. SPSS version 25 testing with normality testing, if the data is normally distributed then continue using One-Way-ANOVA testing, if it is not normally distributed then Kruskal-Wallis testing is carried out. Bivariate analysis is used to determine the correlation between two variables.

Ethical Informations

The study was approved by Health and Research Ethical Committee of Dr. Soetomo General Hospital (reference 14/SC/1333).

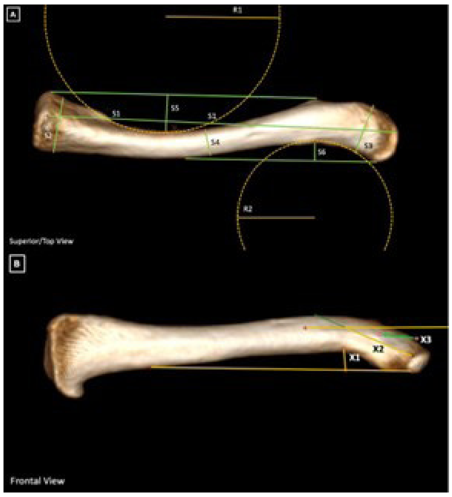

Figure 1: Geometry Morphology of Clavicle Bone From 3D CT scan. A) From Top View B) Frontal View.

RESULTS

The 1426 patients who had CT scan data in the study period, 385 patients were obtained by simple random sampling who met the inclusion and exclusion criteria for this study. Of the 385 patients, the median age was 44 (17-74) years (Figure 2). Females accounted for more than half (54.3%) of the sample (Figure 3).

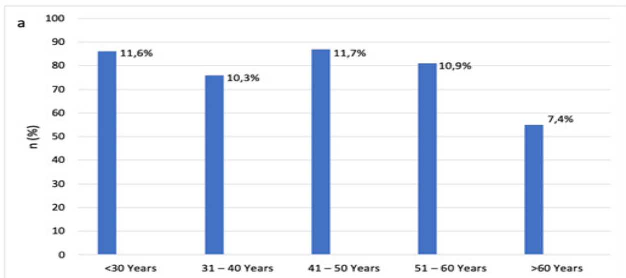

Figure 2: Demographic Characteristic of age.

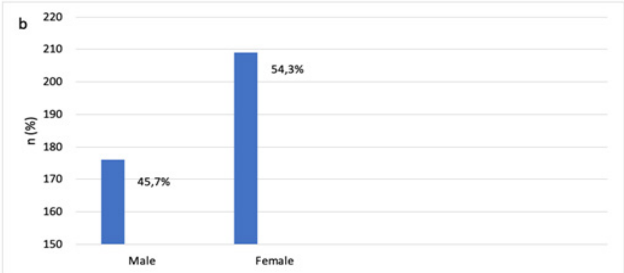

Figure 3: Demographic characteristic of sex.

Geometry Morphology of Clavicle Bone Top View

The clavicle bone morphology geometry data was analyzed from a total of 741 clavicle bone samples, consisting of 342 male clavicle bone samples (46.2%) and 399 female clavicle bone samples (53.8%). Of the 741 bone samples, 375 were left-sided clavicle bones (50.6%) and 366 were right-sided clavicle bones (49.4%). The measured top-view geometry data were mean lateral to medial bone length (S1), sternal diameter (S2), acromial diameter (S3), central diameter (S4), medial curve depth (S5), lateral curve depth (S6), medial curve radius (R1) and lateral curve radius (R2). There were no significant differences between the left and right clavicle bone geometry parameters.

In Table I, among males (n=342), the length of the bone from lateral to medial edge (S1) was significantly longer compared to females (n=399) (p = 0.000). Similarly, sternal diameter (S2), acromial diameter (S3), middle diameter (S4), medial curve depth (S5), lateral curve depth (S6), and medial curve radius (R1) were all significantly larger in males compared to females ($p < 0.001$ for all variables). Conversely, lateral curve radius (R2) was significantly larger in females compared to males ($p < 0.001$). These findings indicate clear gender-based differences in clavicle morphometry, with males generally exhibiting larger dimensions compared to females.

Table I: Association of Clavicle Morphometry in the Superior View with Gender and Age

Variable	Gender		p-value*	Age Group					p-value*
	Male (n=342)	Female (n=399)		<30 years old (n=167)	31 – 40 years old (n=148)	41 – 50 years old (n=167)	51 – 60 years old (n=154)	>60 years old (n=105)	
Length of the bone from lateral to medial edge – S1 (cm)	14,36 (11,97 – 16,50)	13,03 (0,72)	0,000**	13,65 (11,21 – 16,00)	13,51 (0,84)	13,72 (0,95)	13,51 (0,98)	14,25 (10,97 – 15,76)	<0,001**
Sternal diameter – S2 (mm)	22,76 (16,80 – 31,30)	21,52 (2,30)	<0,001**	21,33 (16,40 – 27,60)	22,01 (2,38)	22,24 (2,46)	22,46 (2,54)	22,53 (2,51)	0,001**
Acromial diameter – S3 (mm)	22,98 (2,07)	13,38 (8,76 – 21)	0,000**	21,90 (2,47)	22,17 (2,35)	21,80 (2,61)	21,80 (2,34)	22,60 (2,23)	0,049
Middle diameter – S4 (mm)	13,37 (8,76 – 21,10)	12,33 (8,52 – 18,40)	<0,001**	13,00 (8,52 – 18,62)	12,73 (8,66 – 18,74)	12,47 (8,84 – 21,10)	12,75 (8,52 – 18,82)	13,98 (9,13 – 18,79)	0,005**
Medial curve depth – S5 (mm)	12,93 (6,44 – 23,20)	10,76 (7,54 – 20,40)	0,000**	11,35 (7,54 – 18,70)	11,01 (6,44 – 20,40)	11,46 (9,11 – 21,70)	11,57 (7,59 – 19,70)	12,63 (8,15 – 23,20)	<0,001**
Lateral curve depth – S6 (mm)	12,49 (7,06 – 18,10)	10,59 (5,51 – 14,70)	0,000**	11,12 (6,44 – 14,77)	10,83 (5,81 – 15,80)	11,19 (6,06 – 18,10)	10,98 (5,51 – 16,20)	12,14 (1,82)	<0,001**
Medial curve radius – R1 (mm)	34,36 (26,70 – 43,30)	30,73 (25,00 – 43,80)	0,000**	32,24 (4,04)	31,22 (25,14 - 43,80)	32,50 (25,20 – 43,30)	33,02 (4,18)	34,24 (3,70)	<0,001**
Lateral curve radius – R2 (mm)	25,53 (22,00 – 30,00)	26,44 (1,28)	<0,001**	26,08 (1,65)	26,17 (1,64)	26,05 (1,71)	26,11 (18,90 – 29,20)	26,39 (22,13 – 29,30)	0,904**

The results are expressed as mean (SD) or median (minimum-maximum). *Independent T-test **Mann-Whitney U test

In the Table I, association between clavicle morphometry in the superior view and age group was examined. Various morphometric parameters, including the length from the lateral to medial edge (S1), sternal diameter (S2), acromial diameter (S3), middle diameter (S4), medial curve depth (S5), lateral curve depth (S6), medial curve radius (R1), and lateral curve radius (R2), were analyzed across different age groups: <30 years, 31–40 years, 41–50 years, 51–60 years, and >60 years. Significant differences were found in several morphometric parameters across age groups. Specifically, the length from the lateral to medial edge (S1), sternal diameter (S2), Acromial Diameter (S3), middle diameter (S4), medial curve depth (S5), lateral curve depth (S6), and medial curve radius (R1) exhibited significant differences ($p < 0.05$). Post-hoc analyses revealed that these differences were primarily driven by variations between age groups. However, no significant differences were observed in acromial diameter (S3) and lateral curve radius (R2) across age groups. These findings suggest age-related variations in clavicle morphometry, emphasizing the importance of considering age-specific differences in clinical and anatomical studies involving the clavicle.

Geometry Morphology of Clavicle Bone Frontal View

The complete frontal clavicle bone morphology geometry data of all study samples are listed in Figure 4.

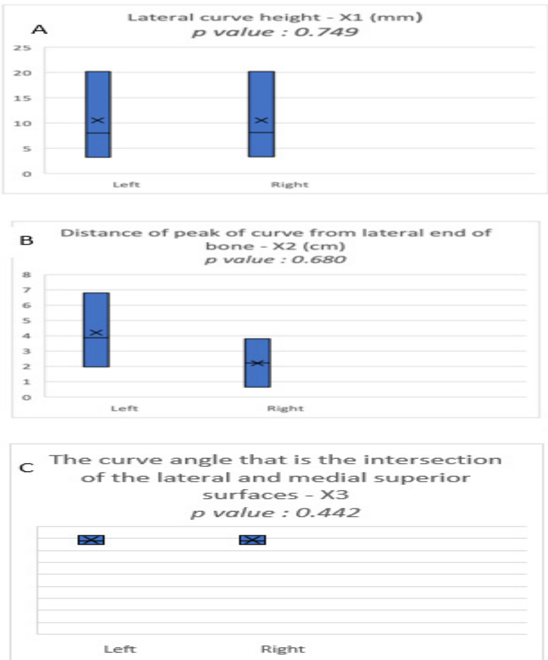

Figure 4: Graphics of Clavicle Bone Morphology Frontal View. (a) Lateral curve height - X1 (mm), (b) Distance of peak of curve from lateral end of bone - X2 (cm), and (c) The curve angle that is the intersection of the lateral and medial superior surfaces - X3.

From the figure 4 there were variables included, lateral curve height (X1), distance from the lateral bone end to the curve peak (X2), and the curve angle (X3). Across both sides, there were no statistically significant differences observed in the lateral curve height (X1) ($p = 0.749$), with median values ranging from 8.07 mm to 8.14 mm. Similarly, the distance from the lateral bone end to the curve peak (X2) did not show significant variation between sides ($p = 0.680$), with median values ranging from 3.80 cm to 3.86 cm. Additionally, the curve angle (X3) exhibited consistent values between sides, with median angles of 24.00 degrees (range: 15.00 – 30.00 degrees), respectively. These findings suggest that there are no significant differences in these specific morphometric characteristics of the clavicle between the left and right sides.

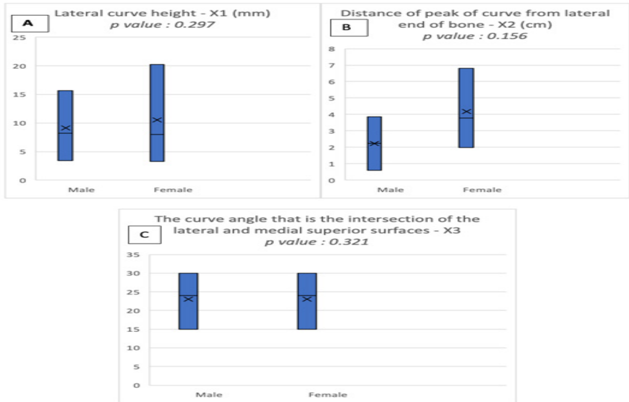

Figure 5: Relationship between Frontal Clavicle Bone Morphometry and Gender. a. Lateral curve height - X1 (mm), b. Distance of peak of curve from lateral end of bone - X2 (cm), c. The curve angle that is the intersection of the lateral and medial superior surfaces - X3.

The bivariate analysis comparing morphometric variables between genders yielded non-significant results for all measured parameters. The variables included lateral curve height, distance from the lateral bone end to the curve peak, and the curve angle (intersection of superior lateral and medial surfaces). Among the male participants (n=342), the mean lateral curve height was 8.22 mm (range: 3.40 – 15.70 mm), while for females (n=399), it was 8.03 mm (range: 3.28 – 20.20 mm). The difference was not statistically significant ($p = 0.297$). Similarly, the distance from the lateral bone end to the curve peak showed no significant variation between genders, with males averaging 3.86 cm and females 3.77 cm ($p = 0.156$). Additionally, the curve angle exhibited comparable values between males and females, with both groups having a median angle of 24.00 degrees (range: 15.00 – 30.00 degrees), and no significant difference was observed ($p = 0.321$). These findings suggest that gender does not play a significant role in determining these specific morphometric characteristics of the clavicle (Figure 5).

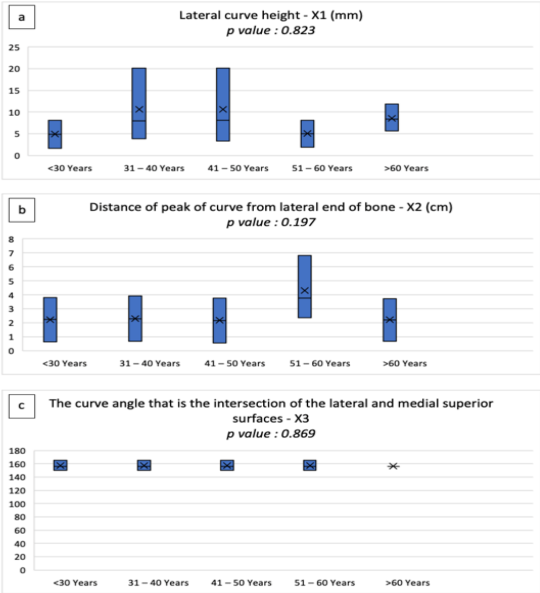

Figure 6: Relationship of Frontal View Clavicle Bone Morphometry with Age Group. (a) Lateral curve height - X1 (mm), (b) Distance of peak of curve from lateral end of bone - X2 (cm), and (c) The curve angle that is the intersection of the lateral and medial superior surfaces - X3.

The bivariate analysis comparing morphometric variables across different age groups showed non-significant results for all measured parameters. These variables included lateral curve height (X1), distance from the lateral bone end to the curve peak (X2), and the curve angle (X3). Across the age groups, there were no statistically significant differences observed in the lateral curve height (X1) ($p = 0.823$), with mean values ranging from 7.95 mm to 8.32 mm. Similarly, the distance from the lateral bone end to the curve peak (X2) did not show significant variation across age groups ($p = 0.197$), with mean values ranging from 3.72 cm to 3.92 cm. Additionally, the curve angle (X3) exhibited consistent values across age groups, with median angles of d 24.00 degrees (range: 15.00 – 30.00 degrees), respectively. These findings suggest that age does not play a significant role in determining these specific morphometric characteristics of the clavicle (Figure 6).

DISCUSSION

This study is a retrospective study that aims to determine normal shoulder collarbone anthropometry in the adult population in Indonesia based on 3-dimensional CT scans. The morphometric results are expected to be a reference for the size of the clavicle pre-contour plate that is in actual size with the anatomical conditions of the Indonesian population to reduce the risk of implant prominent, screw loosening and malunion. (8)

In this study, we examined the morphometry of the clavicle bone in top view (lateral to medial bone length (S1), sternal diameter (S2), acromial diameter (S3), central diameter (S4), medial curve depth (S5), lateral curve depth (S6), medial curve radius (R1) and lateral curve radius (R2)) and front view (lateral curve height (X1), distance of curve apex from lateral end of bone (X2), curve angle (X3)). We also examined clavicle bone differences by side (left and right), gender, and age group.

From this study, the length of the clavicle bone in the normal shoulder of the Indonesian population from the lateral to medial edge in this population was 13.74 (10.97-16.50) cm. This figure is smaller than the results of studies in the populations of China (9,10), India (11), Germany (12), France (13), South Africa (14), and Tanzania (15). The normal shoulder clavicle sternal diameter of the Indonesian population (2.20 (1.47-3.13) cm) was shorter than the figures reported for the Chinese, European, Indian, and South African populations. However, the acromial diameter (2.20±0.24 cm) and medial diameter (1.28 (0.85-2.11) cm) figures were similar to findings in previous studies in these countries. Furthermore, the medial and lateral curve depths in normal shoulders of the Indonesian population were 11.47 (6.44-23.20) mm and 11.17 (5.51-18.10) mm, respectively. The radius of the medial and lateral curves of the normal shoulder of the Indonesian population were 32.64 (25.00-43.80) mm and 26.15 (18.90-30.00) mm. The curve depth and radius of the Indonesian population appeared to be smaller than previous studies in these countries.

In our study, significant results were found in relation to age groups. These findings are associated with the fact that each generation has varying heights. Typically, each successive generation tends to be taller, resulting in significant differences in clavicle morphometry. This finding is supported by other research linking clavicle length to body height. Therefore, our study reinforces the relationship between anthropometric characteristics such as body height and clavicle morphometry, providing further insight into the role of age groups in determining clavicle dimensions. Clavicle has an additional forensic advantage of being having extended growth period sufficient to indent additional identifying features in it. Other research, could not detect the age of terminal growth in either sex because growth was ongoing in most patients in the oldest group (25 years old).

From the frontal view of the clavicle bone, the median lateral curve height, median curve apex distance from the lateral end of the bone, and median curve angle were 8.09 (3.28-20.20) mm, 3.85 (1.94-6.87) cm, and 24.00 (15.00-30.00) cm, respectively. However, no study has examined the height of the lateral curve of the clavicle bone, so there is no comparison. In Table 1, all morphometric parameters of the upper visible clavicle bone in previous studies have been summarized. Generally, these differences are thought to be caused by genetic differences due to race. In a study of the radius and tibia bones of men of European, African and South

Asian race in the UK, it was found that men of European and African race had wider and longer bones than men of Asian ethnicity, even after controlling for weight and height (16).

In this study, there was no significant difference between the left and right clavicle bones. This is in contrast to the findings of Andermahr et al. where the left medial radius of curvature (R1) was larger than the right (7.4±1.2 cm with 6.9±1.3 cm, $p<0.05$) while the left lateral radius of curvature (R2) was significantly smaller than the right (3.7±1.3 cm with 4.2±1.5 cm, $p<0.05$) (12). This is thought to be due to the development of more muscles on the right side, especially in the right-handed population (12).
Our study also found all parameters of the male clavicle bone to be longer than the female. This is consistent with the findings of another study where the clavicle bone length of males was 14.2 mm longer than females (11). In addition, the same study also showed that the male clavicle was also significantly wider in the parameters of acromial diameter, central diameter, sternal diameter, medial and lateral curvature radius, medial curvature depth, but not lateral curve depth. Another study in an Indian population also showed significant differences in male and female clavicle bones measured directly (17). In the Chinese population, differences between males and females were also evident in all parameters of the upper visible clavicle bone except the lateral curve radius (9). In another study by Qiu, male bone length was 17.3 mm longer than female bone (10). In previous studies, there were several other methods used to obtain clavicle morphometry, namely measuring the true length of the clavicle bone with CT scan reconstruction (8) or the true length of the clavicle bone directly with calipers (15). This difference in male and female bone parameters may be due to men having higher mineral content and bone density than women. In addition, it may also be due to genetic, hormonal, nutritional and environmental factors (17). The implication of these findings is that plate making for clavicle fractures can adjust for the difference in clavicle bone size in males and females. This study uses the apparent length method by utilizing 3D reconstruction so it is necessary to be careful in interpreting the numbers listed in this research report as a reference for plate making.

CONCLUSION

The morphometric findings of adult patients in East Java indicate a shorter clavicle length compared to several other countries. Interestingly, there was a significant correlation observed between clavicle morphometry and both age group and gender. This correlation suggests that age group and gender play significant roles in determining clavicle dimensions among the adult population in East Java. These findings highlight the importance of considering demographic factors when assessing clavicle morphology, which can have implications for various fields such as orthopedic surgery, forensic anthropology, and biomechanical studies.

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