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Original Article

Anatomy Section

Structure of Clavicle In Relation to Weight Transmission

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ABSTRACT

Aims and Objectives: It is a known fact that weight of upper limb is transmitted to the axial skeleton through clavicle. The present study is an attempt to correlate pattern of compact and trabecular bone of clavicle as a weight transmitting bone.

Materials and Methods: Sixty clavicles were studied from right and left sides of 30 cadavers donated to the Anatomy department, Pramukhswami Medical College, Karamsad, India. The study was focused on the thickness of compact bone of clavicle and trabecular pattern of this bone.

Results: Cancellous bone: Cancellous bone near both ends of clavicle presented meshwork of thin bony plates. Between the conoid tubercle and area for attachment of costo-clavicular ligament, cancellous bone showed a definite pattern.

Thickness of compact bone: The compact bone was thicker between conoid tubercle and area for attachment of costo-clavicular ligament. At midshaft point thickness of compact bone was maximum.

Conclusion: The structure of clavicle between conoid tubercle and area for costoclavicular ligament showed thick compact bone and definite pattern of cancellous bone. This structure of clavicle between conoid tubercle and area for attachment of costo-clavicular ligament transmits weight from lateral to medial direction and this knowledge of clavicular structure will also be useful to orthopedic surgeons to deal with clavicular fractures and other abnormalities.

Keywords: Compact bone, Cancellous bone, Trabeculae

INTRODUCTION

Clavicle is a link between axial and appendicular skeleton. There are many reports regarding functional aspects of clavicle. Various studies have been done on functions of clavicle by different researchers like Inman et al., Abbott et al., Frutos [1-3]. Inman et al., [1] mentioned that the function of the clavicle is closely integrated with the shoulder complex and any restriction of motion at either of its joints is promptly reflected in the total range of motion at shoulder. Abbott et al., and Frutos have suggested the role of clavicle in transmitting force from the upper limb to the axial skeleton [2,3].

Different studies have been done on trabecular pattern of bones involved in weight transmission, like femur [4,5], talus [6,7] and calcaneum [8,9]. According to those studies, weight transmitting bones show pattern of cancellous bone following the route of weight transmission. Accordingly, trabecular pattern in femur (neck region), talus (neck and body) and calcaneum (body) are arranged parallel to the line of weight transmission.

The present study is undertaken to correlate structure of clavicle with its role in transmission of weight from upper limb to the axial skeleton. The study was focused on the thickness of compact bone and trabecular pattern of cancellous bone in clavicle.

MATERIALS AND METHODS

Total 60 clavicles were studied from right and left sides of 30 cadavers donated at the Anatomy department, Pramukhswami Medical College, Karamsad. This study was undertaken for the period of three years during 2012 to 2014. Broken clavicles were excluded from the study. The clavicles used in this study were taken from the cadavers ranging from 60-89 years of age. Among them 10 cadavers were females and other 20 were males.

Clavicles were removed by cutting attached muscles and ligaments. They were disarticulated at both ends. After taking out, the clavicles were tagged with cadaver numbers and put in sunlight for drying for two weeks. Clavicles were divided into two groups. Group A contained 30 clavicles (one from each cadaver, left or right sided). Group B contained rest of the 30 clavicles.

Group A: 30 clavicles of this group were studied for the arrangement of cancellous bone.

For removal of compact bone, clavicles were treated with 5% HCl solution. After that, they were washed properly under tap water and dried. To expose the trabeculae of cancellous bone, the outer compact bone was removed from its anterior, superior and posterior surfaces, with the help of bone nibbler, toothed forceps and pointed forceps. Direction of trabeculae was traced from its lateral to medial end. The cancellous pattern of clavicle was studied in four divisions of clavicle. As shown in [Table/Fig-1], clavicle was divided into four divisions from lateral to medial end, division I,II,III and IV. The part of clavicle lateral to the conoid tubercle was division I. Division II extends from conoid tubercle to midshaft. Division III extends from midshaft to the area for the attachment of costo-clavicular ligament. Division IV extends from this area till medial end of clavicle [Table/Fig-1].

Group B: Thirty clavicles were studied for the thickness of compact bone. Each clavicle was cut at 4 levels with the help of the saw [Table/Fig-2].

Level 1 – Transverse section of clavicle lateral to conoid tubercle.

Level 2 – Transverse section of clavicle medial to conoid tubercle.

Level 3 – Transverse section of clavicle at the midshaft

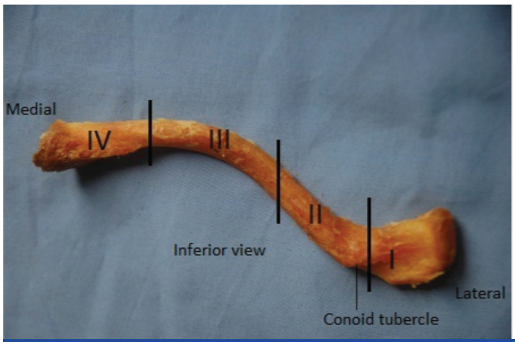
Level 4 – Transverse section of clavicle near the medial end.

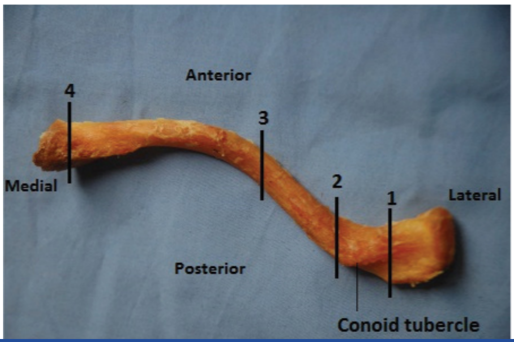
Thickness of compact bone was measured at 4 points of each 4 levels with the help of electronic caliper with accuracy of 0.01 mm. In each segment mean of 4 measurements was calculated [Table/Fig-2,3].

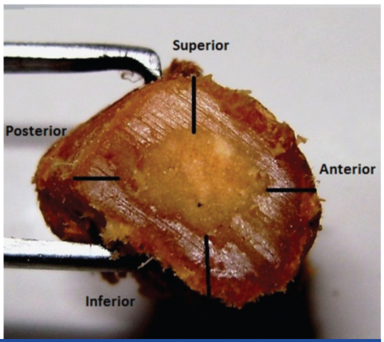
RESULTS

Trabecular pattern of clavicle: - (GROUP - A)

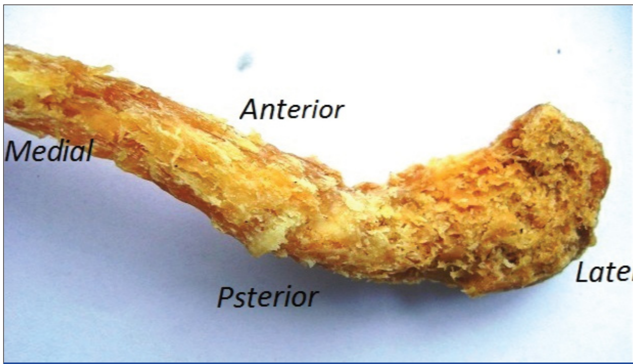
The spongy bone of clavicle consists of trabeculae radiating in different directions forming honeycomb pattern and apart from that thin plates disposed vertically or horizontally. The honeycomb



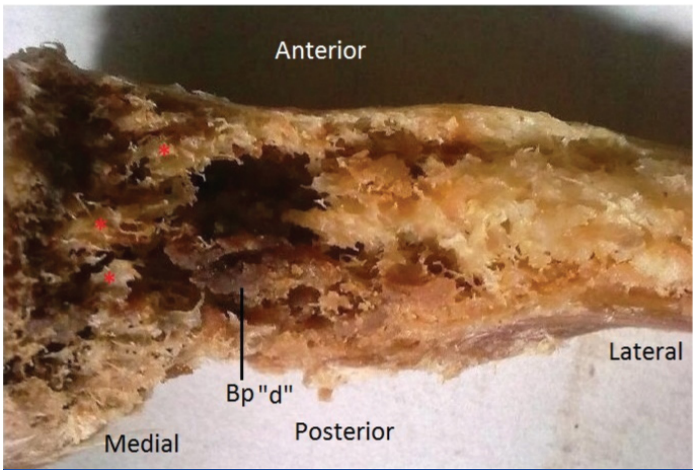




[Table/Fig-1]: Inferior view of left clavicle showing 4 segments - I, II, III, IV **[Table/Fig-2]:** Inferior view of left clavicle showing levels of transverse section (1,2,3,4)
[Table/Fig-3]: Level 3 – Transverse section of clavicle at midshaft



[Table/Fig-4]: Superior view of lateral half of right clavicle, showing trabecular pattern of division I and II



[Table/Fig-5]: Superior view of medial end of right clavicle, showing trabeculae in division IV
* shows thin plates in 'area c' of division IV, Bp – Bony plate

patterned meshwork of trabeculae is present in all 4 divisions occupying the outer part. While, trabecular pattern was disposed vertically and horizontally in the centre.

Division I: Division I was showing uniform structure in all 30 clavicles. In this area cancellous bone was showing honeycomb pattern, where very thin and small bony plates were overlapping each other and were arranged in all directions [Table/Fig-4].

Division II: - Honeycomb pattern of trabecular meshwork was found in superficial portion beneath compact bone. Deep to that, two to three bony plates were arranged horizontally throughout the extent of division II. These bony plates were thicker than those found in division III. This horizontal pattern of bony plates was found uniformly in division II of all 30 clavicles [Table/Fig-4].

Division III: - Honeycomb pattern of trabecular meshwork was found in superficial portion beneath compact bone. Deep to that, two to three horizontal trabecular plates were found in 14 clavicle specimens out of 30. In 16 clavicle specimens, division III was occupied with very small and ill-defined trabeculae.

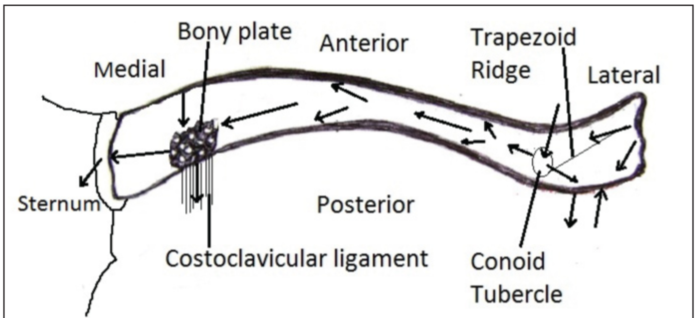
Division III showed variation in the pattern of cancellous bone. In 14 clavicles, horizontal bony plates were observed. Very small and

Level	No. of specimens	Mean±Standard Deviation	Standard Error
1	30	1.18±0.269	0.049
2	30	1.86±0.490	0.089
3	30	2.36±0.595	0.109
4	30	1.01±0.295	0.054
Total	120	1.60±0.692	0.063

[Table/Fig-6]: Descriptive statistics of thickness of compact bone

Level (I)	Level (J)	Mean Difference (I-J)	Standard Error	Significance (p-value)
Level 1	Level 2	-0.680(*)	0.102	0.001
	Level 3	-1.181(*)	0.119	0.001
	Level 4	0.169	0.073	0.136
Level 2	Level 1	0.680(*)	0.102	0.001
	Level 3	-0.501(*)	0.141	0.005
	Level 4	0.849(*)	0.104	0.001
Level 3	Level 1	1.181(*)	0.119	0.001
	Level 2	0.501(*)	0.141	0.005
	Level 4	1.350(*)	0.121	0.001
Level 4	Level 1	-0.169	0.073	0.136
	Level 2	-0.849(*)	0.104	0.001
	Level 3	-1.350(*)	0.121	0.001

[Table/Fig-7]: Descriptive analysis for comparison of the thickness of compact bone at different levels of clavicle
The mean difference is significant when p-value is less than 0.05.



[Table/Fig-8]: Inferior view of left clavicle, arrows are showing line of weight transmission from upper limb to the axial skeleton

ill-defined trabeculae were observed in division III in 16 clavicles.

Division IV: This division showed uniform pattern in all 30 clavicles. Honeycomb pattern of trabecular meshwork was found in superficial layer beneath compact bone. In deeper part of this division, a thick bony plate'd' was observed [Table/Fig-5]. It was situated more near the lateral aspect of division IV of clavicle, superimposed on the area for the attachment of costoclavicular ligament. This plate was nearly oval in shape and 7 mm X 5 mm in dimensions. Multiple perforations were observed in it.

The area of this division around the bony plate was divided into 3 areas [Table/Fig-5]. Area a– lateral to the bony plate, Area b – anterior to the bony plate "d" and Area c - near to sternal articular surface.

Area a: In all 30 clavicles, this area was occupied by vertically arranged thin bony plates connecting horizontal plates of division III to the thick bony plate.

Area b: This area was occupied by honeycomb patterned trabecular meshwork in the superficial region. After removing that, vertical trabecular plates were observed extending from thick bony plate to the compact bone of anterior surface of clavicle.

Area c: After removing that honeycomb patterned trabeculae, vertical trabeculae were found extending from thick bony plate to sternal articular surface. Most antero-inferior aspect of 'area c' was occupied by honeycomb patterned trabecular meshwork [Table/Fig-4].

In division IV, thick bony plate, trabeculae in area a, b and c were observed uniformly in all 30 clavicles.

Thus, the pattern of cancellous bone in division I, II and IV was same in all clavicles, while division III presented two types of patterns, well defined horizontal plates in 14 clavicles and ill-defined small plates in 16 clavicles.

Thickness of compact bone in clavicle:- (Group - B)

The thickness of compact bone was measured in 30 clavicles of group –B. It was measured in millimeters, at 4 levels in each clavicle [Table/Fig-2,3]. Mean, standard deviation and standard error of the results of thickness of compact bone at each level in all 30 clavicles were calculated [Table/Fig-6].

The thickness of compact bone at each level was compared with that at other three levels. Mean differences were calculated [Table/Fig-7]. P-value of less than 0.05 was taken as significant for assessing thickness of compact bone at different levels. The thickness of compact bone at level 1 was significantly less than that at level 2 and level 3. But the difference between thickness at level 1 and 4 was statistically not significant because p-value is more than 0.05. The thickness of compact bone at level 2 and level 3 were significantly different from other three levels. The thickness of compact bone at level 4 was significantly different from level 2 and 3, but the difference between thickness at level 4 and 1 was statistically not significant [Table/Fig-7].

DISCUSSION

Clavicle is a bone in the route of weight transmition. The trabecular pattern of cancellous bone has been studied in femur, talus, calcaneum, which are the bones in the route of weight transmission of the lower limb. Hence the present study was undertaken for the trabecular pattern as well as the thickness of compact bone of clavicle. Findings were correlated with the route of weight transmission.

Femur was the first bone studied for its architectural structure. Head of femur is exposed to weight transmitted by hip bone. According to Hall [4] it presents two types of trabeculae (Primary and Secondary). The primary trabeculae run parallel to the lines of force transmitted through the bone and the secondary trabeculae are oblique to primary trabeculae. One set of compression (primary) trabeculae arise from the upper half of the articular surface of head of femur and reach till the lower border of the neck of femur. Another set of compression trabeculae arise from lower half of head of femur and reach to the upper border of neck of femur. So both sets of compression trabeculae cross each other at the central dense area. As mentioned by Datta [5], the bony trabeculae in the interior of the upper end of femur are arranged to withstand the weight of the body transmitted through the femoral head.

Pal et al., described architecture of the cancellous bone of the human talus [7]. Generally vertical forces are transmitted onto the trochlear surface and body of talus, its trabeculae run predominantly vertically. Then the talus transmits the force anteriorly to the navicular bone. There is an abrupt change in the direction of trabeculae from a vertical arrangement in the body to an oblique arrangement in the neck. The head of the talus, which articulates with the navicular bone, has predominately horizontal trabeculae that are continuous with those of the neck, and run postero-anteriorly.

Lockhart et al., have described the normal trabecular pattern of the calcaneum. Compression trabeculae were disposed in two sets [10]. One originates at the subtalar articular surface and diverges downwards and backwards. The second set of compression trabeculae pass anteriorly from the subtalar articular surface to the articulation with the cuboid bone. These studies indicate that all weight transmitting bones have a common architectural pattern. In all these bones, trabeculae were arranged in the line of weight transmission.

The clavicle receives weight from the upper limb at the conoid tubercle through coracoclavicular ligament [11]. From this point weight is transmitted medially to the axial skeleton. Clavicle has been studied for its cortical thickness by many researchers [12-14]. According to Barnett et al., the clavicular cortical thickness falls with age in both sexes and more strikingly in elderly females [12]. According to Urist et al., [13] the cortical thinning indicates a generalized osteoporosis, because the reduction in bone mass occurs equally in cancellous as well as in cortical bone. Anton has described width of clavicular cortex in osteoporosis [14]. Thinning of upper cortex of clavicle might help in the diagnosis of osteoporosis. With increasing age, due to osteoporotic changes in the bone, there is generalized loss of volume of bone matrix. Loss of trabecular bone starts up to ten years before than the loss of cortical bone begins [15].

In present study, cancellous bone in division I showed honeycomb pattern in all 30 clavicles, indicating no clear pathway for weight transmission [Table/Fig-4]. The thickness of the compact bone was minimum in this division. Thus, the cancellous bone and thinness of compact bone suggested minimum role of this division in weight transmission [Table/Fig-8]. In division II there was gradual increase in the thickness of compact bone from conoid tubercle to the midshaft. The cancellous bone showed two or three horizontal plates.

[Table/Fig-4]. Thick compact bone and definite pattern of cancellous bone were correlating with the direction of weight transmission from conoid tubercle to midshaft [Table/Fig-8].

Division III showed gradual decrease in the thickness of compact bone from midshaft to the attachment of costo-clavicular ligament. The cancellous bone in division III showed horizontal plates in some specimens and very thin and small ill-defined trabeculae in others [Table/Fig-5]. In division IV bony plate'd' was a constant feature in all clavicles [Table/Fig-5]. Radiating trabecular pattern were seen around this bony plate.

There was gradual decrease in the thickness of compact bone from division III to division IV. This indicated that, more weight from division III is transmitted to plate 'd' through cancellous bone. The plate 'd' was corresponding with the area for the attachment of costo-clavicular ligament. The tight costo-clavicular ligament is transmitting large amount of weight through plate 'd' to the first rib [Table/Fig-8]. This was supported by very ill-defined thin trabeculae in area b and c of division IV and minimum thickness of compact bone in this division. The force could also be transmitted medially from thick bony plates to the sternal articular surface of clavicle through oblique and vertical bony trabeculae of division IV. Further, this force would be transmitted through sternoclavicular joint to sternum [Table/Fig-8].

The thickness of compact bone in clavicle gradually increases from conoid tubercle to midshaft. Trabecular pattern was horizontal from conoid tubercle to mid shaft. This correlates with the fact that force from conoid tubercle to mid shaft is transmitted mainly by compact bone and horizontal trabeculae.

Medial to mid shaft there was gradual decrease in thickness of compact bone. While trabecular pattern showed either horizontal or ill-defined trabeculae reaching up to thick bony plate 'd' at the medial third of the bone. Medial to this bony plate, bone was showing honeycomb trabecular pattern. This correlates with the fact that from midshaft to thick bony plate, the force is transmitted by compact bone and horizontal trabecular plates. This suggests that, large magnitude of force from midshaft is transmitted to the costoclavicular ligament through this plate. While remaining weight is transmitted by honeycomb trabeculae to the sternoclavicular joint [Table/Fig-8].

Thus the clavicle receives weight of upper limb mostly through coracoclavicular ligament and it further transmits the weight to the axial skeleton mostly through costoclavicular ligament. The trabecular patterns of clavicle follow the route of weight transmition from lateral to medial end of clavicle [Table/Fig-8]. It was observed that clavicle showed thick layer of compact bone and definite pattern of cancellous bone between conoid tubercle and bony plate'd' superimposing facet for costoclavicular ligament. The two extreme ends of clavicle (lateral to conoid tubercle and medial to the bony plate'd') were devoid of definite pattern of cancellous bone and consist of very thin layer of compact bone. The structure of clavicle plays vital role in weight transmition of the upper limb to the axial skeleton.

CONCLUSION

Weight from conoid tubercle is transmitted through thick compact bone as well as definite pattern of trabeculae of cancellous bone. It is quite possible that at the medial end, the large amount of force passes from plate'd' to first rib through costo-clavicular ligament. While remaining amount may pass from sterno-clavicular junction. This knowledge of clavicular structure will also be useful to orthopedic surgeons to deal with clavicular fractures and other abnormalities.

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