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Original Research Article

STUDY OF VARIATIONS IN NUTRIENT FORAMEN OF DRIED HUMAN CLAVICLE AND ITS RELATION WITH OTHER CLAVICULAR PARAMETERS

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ABSTRACT

Background: Clavicle, a modified long bone belonging to shoulder girdle, is the most commonly fractured bone of the upper extremity following fall on an outstretched hand. Nutrient foramen of long bones allows the passage of nutrient artery. Preservation of nutrient artery is very important for fracture healing of long bones. **Objectives:** This study is aimed at analysing the relation between location of nutrient foramen on clavicle and other clavicular parameters as well as studying the variations in number, location and direction of nutrient foramina. **Materials and Methods:** This study was performed on 80 dry clavicles without age and gender records. Some clavicle parameters and nutrient foramen parameters were measured and the relationship between them was analysed. Measurements were performed using a digital calliper. **Result:** A total of 99 nutrient foramina were studied on 80 dry clavicles. All the studied clavicles had at least one nutrient foramen, and they were all directed towards the acromial end of clavicle. 61 clavicles (76.2%) had a single nutrient foramen. Double nutrient foramina were found in 19 clavicles (23.8%). There was a positive correlation between DFant/DFpost (distance between Nutrient foramen and anterior border/distance between nutrient foramen and posterior border) and vertical thickness of sternal end (VTs). Sagittal thickness of sternal end (STs) had a positive correlation with distance of nutrient foramen from sternal end (DFS). The nutrient foramina were mainly distributed on the posterior surface (51.5%) and inferior surface (46.5%) with only 2% being seen on superior surface of clavicle. The mean Foraminal Index was 48.43 ± 8.97. 65 clavicles (81.25%) showed Type 2 localisation of nutrient foramina. **Conclusion:** The relationship between morphometry of nutrient foramen and some clavicular parameters were studied. This could be of value to orthopaedic surgeons in preserving the vitality of clavicle during internal fixations performed for the treatment of clavicular fractures.

INTRODUCTION

Clavicle, a modified long bone, is a bone of the shoulder girdle and lies horizontally across the root of the neck. It acts as a strut that allows the arm to move freely on the trunk and plays the unique role of transmitting the weight of axial skeleton to the appendicular skeleton. The nutrient foramen is usually located along the inferior surface of the shaft of clavicle at the lateral end of subclavian groove,[1] at the junction of medial two thirds and lateral one thirds. In addition to nutrient artery of clavicle, which is the suprascapular artery,[1] it can also give passage to the supraclavicular nerve.[2]

The clavicle is the most commonly fractured bone in the body and is usually fractured at its weakest point which is the junction of middle thirds and lateral thirds.[3] This is usually where the nutrient foramen is located. Most clavicular fractures though treated non-operatively, symptomatic non-unions require surgical intervention.[4] These cases have shown good results with external and internal fixation with nails, plates, screws and surgical grafting,[7] which requires knowledge of nutrient arterial supply. Failure to preserve nutrient artery can lead to neurovascular complications even after surgical repair of fractures.[8] Healing is often delayed in stress fractures associated with nutrient artery rupture.[5] Additionally the development of new surgical and resection techniques and vascular bone grafts require the preservation of nutrient artery entering nutrient foramen.[6]

A number of studies had been conducted in India on the variations of nutrient foramen in clavicle.[9,10,11] However, these studies did not explore whether the position of nutrient foramen affected the morphology of clavicle such as its length and thickness. Therefore this study aims to examine whether any relation exists between location of clavicular nutrient foramen and the morphological features of clavicle.

MATERIALS AND METHODS

The study was carried out on 80 dried clavicles (46 right sided clavicles and 34 left sided clavicles) in the Anatomy Department of Jagannath Gupta institute of Medical Sciences and Hospital, Budge Budge, Kolkata, West Bengal. The study period was from November 2024 to June 2025. There were no available records about the age and gender of the bones nor could matching be possible whether the bones came from the same person. Bones with deformities such as cracks and healed fractures had been eliminated from the study.

The following parameters of nutrient foramen were recorded. In the presence of more than one foramen, the most prominent one was regarded as the dominant foramen.

1) Number of foramina: The nutrient foramina were identified using a magnifying glass by the presence of a well-marked groove and slightly raised margin at the commencement of the canal.
2) Direction of Nutrient canal: The direction of the canal was determined by using a 24G needle.
3) The location of nutrient foramina with respect to surface and Foraminal Index (FI)
   Type 1 – FI <33%
   Type 2 – 33.3 to 66.6%
   Type 3 - >66.6%
4) Distance of nutrient foramen from sternal end (DFs).
5) Foraminal Index was calculated using Hughe's formula[12]: (DFS/CL) X 100
6) Distance of Nutrient foramen from anterior border (DFant)
7) Distance of Nutrient foramen from posterior border (DFpost)

The clavicular parameters measured were:

1) Total length of the clavicle (CL) using Vernier calliper, ignoring curves of the clavicle.
2) Vertical thickness of sternal end (VTs): Distance between top and bottom points of sternal end.
3) Sagittal thickness of sternal end (STs): Distance between most anterior and posterior points of sternal end
4) Vertical thickness of acromial end (VTa): Distance between top and bottom points of acromial end.
5) Sagittal thickness of acromial end (STa): Distance between most anterior and posterior points of acromial end.

All the distances were measured in millimetres by using a digital calliper. The Foraminal Index was expressed as percentage.

The data were tabulated and analysed using the software SPSS version 16.00. The mean and standard Deviation value of the distances were used for analysis. Pearson correlation test was used to show the correlation. $P < 0.05$ was considered significant. The analysed data was compared with already available data from similar studies done in the past and inference was drawn.

RESULTS

Table 1: Number of Nutrient Foramen on Clavicle

Nutrient Foramen Number	Left (N = 34)	Right (N = 46)	Total (N = 80)
0	0	0	0 (0%)
1	34	27	61 (76.2%)
2	0	19	19 (23.8%)
3	0	0	0 (0%)

Table 2: Position of Nutrient Foramen on Clavicle

Position of Nutrient Foramen	Right Nutrient Foramen (Total = 65)	Left Nutrient Foramen (Total = 34)	Total Nutrient Foramen (N = 99)
Anterior surface	0 (0%)	0 (0%)	0 (0%)
Posterior surface	33 (50.9%)	18 (52.9%)	51 (51.5%)
Superior surface	2 (3.1%)	0 (0%)	2 (2.0%)
Inferior surface	29 (46%)	16 (47.1%)	45 (46.5%)

Table 3: Nutrient Foramen Parameters of Right and Left Clavicles

Parameter	Left Clavicle	Right Clavicle
Distance from sternal end (DFS) (mm)	66.69 ± 13.28 / 65.27 ± 12.39	64.63 ± 13.48
Foraminal Index (FI) (%)	48.55 ± 5.08 / 48.43 ± 8.97	48.38 ± 11.00
Distance of NF from anterior border (DFant) (mm)	9.77 ± 1.03 / 10.17 ± 1.54	10.34 ± 1.83
Distance of NF from posterior border (DFPost) (mm)	3.08 ± 3.56 / 4.12 ± 2.58	4.58 ± 2.29

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Table 4: Localization of Nutrient Foramen on Clavicle

Localization (Based on FI)	Right Clavicle (N = 46)	Left Clavicle (N = 34)	Total (N = 80)
Medial 1/3 (FI < 33.33%)	0 (0%)	0 (0%)	0 (0%)
Middle 1/3 (FI 33.33–66.66%)	31 (38.75%)	34 (42.5%)	65 (81.25%)
Lateral 1/3 (FI > 66.66%)	15 (18.75%)	0 (0%)	15 (18.75%)

Table 5: Clavicular Parameters of Right and Left Clavicle

Parameter	Group	Mean ± SD
Clavicular length (mm)	Left Clavicle	136.58 ± 16.09 / 135.29 ± 13.07
	Right Clavicle	134.71 ± 12.56
Vertical thickness of sternal end (VTs) (mm)	Left Clavicle	23.04 ± 2.13 / 23.11 ± 3.32
	Right Clavicle	23.14 ± 3.84
Sagittal thickness of sternal end (STs) (mm)	Left Clavicle	19.53 ± 4.70 / 19.80 ± 4.14
	Right Clavicle	19.92 ± 4.17
Vertical thickness of acromial end (VTa) (mm)	Left Clavicle	11.27 ± 0.58 / 11.22 ± 1.24
	Right Clavicle	11.20 ± 1.47
Sagittal thickness of acromial end (STa) (mm)	Left Clavicle	26.61 ± 4.69 / 23.28 ± 4.40
	Right Clavicle	21.80 ± 3.57

Table 6: Correlation between Nutrient Foramen Parameters and Clavicular Parameters

Clavicular Parameter	DFS (C / p-value)	FI (C / p-value)	DFant/DFpost (C / p-value)
CL	0.27 / 0.36	–0.23 / 0.44	0.17 / 0.62
VTs	0.34 / 0.29	0.18 / 0.55	**0.62 / 0.04**
STs	**0.59 / 0.03**	–0.39 / 0.18	0.14 / 0.69
VTa	0.28 / 0.09	–0.02 / 0.93	0.40 / 0.24
STa	0.38 / 0.19	–0.23 / 0.32	0.04 / 0.89

C: Pearson correlation coefficient; significant correlations: $p < 0.05$

A total of 99 nutrient foramina were found in 80 clavicles studied. In all the clavicles studied, at least one foramen was present in each clavicle (100%). Double foramina were found in 19 bones (23.8%) – Figure 1. Majority of the clavicles studied (76.2%) had a single foramen. In our study, we did not come across any clavicle which had no nutrient foramina or more than two nutrient foramina. [Table 1]

Figure 1: Right clavicle with two nutrient foramina

Figure 2: Right clavicle with nutrient foramen on superior surface

The foramina were seen on all the surfaces except the anterior surface, being predominantly found on the posterior surface (51.5%). The second commonest site being on the inferior surface (46.5%). Out of 80 clavicles only 2 clavicles had a foramen on the superior surface -Figure 2. [Table 2]

As the mean value of Foraminal Index was 48.43 + 8.97, [Table 3] the most common localisation of nutrient foramen was Type 2 localisation – Figure 3 (located in the middle third of clavicle). There was no foramen with Type 1 localisation. [Table 4]

Figure 3: Left clavicle with nutrient foramen on posterior surface showing type 2 localisation of the foramen

As DFant > DFpost (10.17 > 4.12), the nutrient foramina were located closer to the posterior border of the shaft of clavicle. Observations are tabulated in Table 1, 2, 3 and 4.

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Figure 4: Measurement of length of clavicle

There was a significant positive correlation between DFS and sagittal thickness of sternal end (STs) - $p < 0.05$. There was no significant correlation between Foraminal Index and clavicular parameters. The ratio between DFant and DFpost showed a significant positive correlation with Vertical thickness of sternal end (VTs) – $p < 0.05$.

DISCUSSION

Studies of the arterial blood supply to the clavicle have shown that the bone is supplied by the suprascapular, thoracoacromial, and internal thoracic arteries.[4,13] Knudsen et al. [13] demonstrated that the clavicle is supplied by the periosteal branches of these arteries, that it does not have a distinct nutrient artery, and that the nutrient foramen probably mediates venous drainage. The same study emphasised that a nutrient branch of the suprascapular artery could not be observed or distinguished from the periosteal arteries.[13] Havet et al,[4] found that, in addition to the periosteal branches of thoracoacromial and supraclavicular arteries, a nutrient branch of the suprascapular artery was inserted into the bone through the NF in all cases. Similarly, another study found that the clavicle is supplied by a dominant nutrient artery branching off the suprascapular artery.[14]

Most textbooks mention the presence of a single nutrient foramen in clavicle. The present study had also found most clavicles with single foramen 61 (76.2%) which is similar to the findings in studies conducted by Sharma et al,[15] Sowmiya et al,[16] Dakshayani,[6] Kumar et al.[10] However, studies done by B. Murlimanju et al.[17] Rahul et al,[18] and Sahu Santosh and Dali,[19] show that most clavicles had double foramina. The current study had also found clavicles with double foramina 19 (23.8%) but no clavicles in this study showed absence of foramina or clavicles with more than 2 foramina. Absence of nutrient foramina had been reported in studies by Dakshayani,[6] Kumar et al,[10] Sharmada et al.[9] Since clavicle lacks medullary cavity, absence of nutrient foramina can be justified.[20] Textbook of Gray's anatomy mentions that initially, ossification starts in the shaft of the clavicle in condensed mesenchyme from two primary centers, medial and lateral. The junction of these two centers lies at the junction of the middle and lateral third of the clavicle.[1] In addition to the primary nutrient artery, the presence of two or more arteries separately invading these masses can explain the presence of multiple foramina in the clavicle.

The localisation of NF on the clavicle was determined by calculating the foraminal index (FI).[12] In our study, Nutrient foramen was most frequently (81.25%) located in the middle third of the clavicle (type 2 localisation) followed by lateral thirds of the clavicle (18.75%). Many previous studies have shown similar results to our findings, and have shown that the most common type of localisation is type 2 localisation.[5,17,19,9] However, NF with type 1 localisation was not observed, as in the study by Cihan et al.[5] An FI value above 50 indicates that the NF is further away from the sternal end and closer to the acromial end. In this study, the average FI was found to be less than 50 on both the right and left sides (Table 3). Therefore, most of the foramina in our study were closer to the sternal end. Studies by Aggarwal et al,[11] B. Murlimanju et al,[17] Saha et al,[21] have reported nutrient foramen closer to sternal end.

The traditional view has been that the NF is most commonly located on the inferior surface of the clavicle, lateral to the subclavian groove.[1] However, previous studies have shown that NF can be found not only on the inferior surface of the clavicle, but also on other surfaces.[6,9-11,15-17] In our study, NFs were most commonly located on the posterior surface (51.5%) and secondarily on the inferior surface (46.5%). In addition, two nutrient foramina (2%) were detected on the superior surface and no foramen was detected on the anterior surface. Many previous studies have found that nutrient foramen is mostly located on the posterior surface.[5,10,17,19,21] Literature has also shown that nutrient foramina are rarely seen on anterior and superior surfaces,[17,21] and this is compatible with our study.

A nutrient artery as stated earlier comes from the initial vessels that are present at the site of primary ossification. Schwalbe G explained that before the appearance of epiphyses, there is equal growth at the two ends of a long bone. Hence, the direction of the nutrient foramen should be horizontal, in a vertical long bone before birth.[18] Gradually as the bone grows faster at one end known as the growing end (ends of a growing bone develop from secondary centres of ossification and are supplied by epiphyseal and juxta-epiphyseal arteries), the nutrient canal containing the nutrient artery becomes slanted and is directed away from that end. Hence the direction of the nutrient artery follows the general rule of "growing end theory' and is opposite to the growing end.[22] The sternal being the growing end in clavicle we found that the nutrient canal was directed towards the acromial end in all the clavicles studied. It was observed that the FN was closer to

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the posterior edge (DFpost < DFant) in our study (Table 3). Our findings were consistent with the study of Vatansever et al.[23]

While examining the relationship between clavicular parameters and nutrient foramen parameters, we found a significant positive correlation between sagittal thickness of sternal end (STs) and distance of nutrient foramen from the sternal end (DFS) with p value being 0.03. When we reviewed the literature, we could not find any study that investigated the relationship between the location of nutrient foramen from sternal end and clavicle parameters, and more studies are thereby needed in order to reach more accurate conclusions. A significant positive correlation was also seen between the ratio of distances of nutrient foramen from anterior and posterior border (DFant/DFpost) and vertical thickness of sternal end (VTs) with p value being 0.04. Accordingly, we can say that when nutrient foramen is closer to the posterior border, the sagittal thickness of sternal end of clavicle increases. The study conducted by Yarar et al,[24] also showed a positive relation between vertical thickness of sternal end and ratio of distances of nutrient foramen from anterior and posterior border. The same study also found no significant correlation between foraminal index and any clavicle parameters which is similar to the findings of the present study. Thicker sternal end of clavicle provides more robust bone for fixation devices such as screws and plates. This allows for a more stable construct and potentially reduces the risk of implantation failure. Wider sternal end of clavicle allows the use of larger implants which is beneficial for fixation of fractures in this area.[25] Therefore, understanding the dimensions of sternal end is crucial for preoperative planning , allowing surgeons to select the appropriate implant size and fixation strategy.

CONCLUSION

In our study, it was observed that most of the clavicles had single nutrient foramen and was more common on posterior surface. All the foramina were directed towards acromial end which gives us an idea that sternal end is the growing end. The sagittal and vertical thickness of sternal end of clavicle had a significant positive correlation with distance of nutrient foramen from sternal end and the ratio of distances of nutrient foramen from anterior and posterior border of clavicle respectively. This information could help the orthopedic surgeons in internal fixation surgery as well as bone grafting used for the treatment of nonunited clavicular fractures. Knowledge about the variability of location of nutrient foramen could help the radiotherapists preserve the blood supply during radiation therapy administered for the treatment of malignant bone metastases. Therefore, data from this study can be of use to orthopedic surgeons for treating clavicular fractures, to radiotherapists for treating clavicular malignancies and to other anatomists for further research work on the same topic.

Limitations

This is a dry bone study with no age and gender records. Further studies could be done on dry bone with age and gender records as well as radiological studies for supporting the results of the current study.

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