Morphometric Study of Nutrient Foramina in Dry Human Clavicles in Central India

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ABSTRACT

BACKGROUND

The clavicle or collar bone is a modified long bone. It is the first bone to ossify in the membrane. The inferior surface of shaft of clavicle presents a subclavian groove. A nutrient foramen lies at the lateral end of the groove. The nutrient artery is derived from the supraclavicular or clavicular branch of thoracoacromial artery. A bone is supplied by a nutrient artery which passes through the small tunnel called as nutrient foramina. In orthopaedic procedures to preserve the circulation, the topographical knowledge of the nutrient foramen is important. The study was undertaken to analyse nutrient foramina in adult human clavicles in relation to their number, position, direction, and distribution over bone length.

METHODS

Our study consisted of 67 adult dry human clavicles (31 right sides and 36 left sides). The number, topography and direction of the foramina were studied. The distance of foramina from the sternal end & total length of the clavicles were measured in millimetres by using digital Vernier calipers. The foramen index was calculated by applying the Hughes formula: FI $= \frac{(\text{DNF}}{\text{TL})} \text{x } 100$.

RESULTS

Nutrient foramina were present in all the clavicles. Most of the clavicles have single nutrient foramen. We observed 62 (68.13 %) foramina on the posterior surface mostly in the middle 1 / 3rd region. All the nutrient foramina were directed towards acromial end and the foramina index (FI) was 50.2.

CONCLUSIONS

The topographical knowledge of the nutrient foramen is important in orthopaedic procedures like nail plating, K wire fixation, reduction, internal fixation devices for the treatment of fracture, coracoclavicular ligament repair and in free vascularized bone graft to preserve the circulation.

KEY WORDS

Clavicle, Nutrient Foramina, Nutrient Artery, Foramina Index (FI)

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BACKGROUND

Human beings have adopted upright posture and bipedal locomotion[1] and the arm swings clearly away from the trunk so that the clavicle acts as a strut.[2] The clavicle or collar bone is a modified long bone, subcutaneous throughout and lies horizontally in the body at the root of the neck.[1] The word clavicle is derived from Latin word meaning 'key' and resembles the Latin letter 'f.[3] It has unique features like it is the first bone to ossify in membrane and completes its ossification by about 25 years.

The clavicle has two ends medial and lateral and a shaft which is a cylindrical part. The sternoclavicular joint is formed when the medial (sternal) end articulates with the clavicular notch of the manubrium sterni. The first costal cartilage articulates with the inferiorly extended articular surface of the sternal end. The acromioclavicular joint is formed by the articulation of the lateral (acromial) end with the acromion process of the scapula.[1]

The shaft is divisible into medial two thirds and the lateral one third. The lateral one third of the shaft has two surfaces superior and inferior, two borders anterior and posterior. Its superior surface is subcutaneous. The conoid tubercle and the trapezoid ridge is present on the inferior surface. The medial two third of the shaft is rounded and has four surfaces. Its anterior surface is convex forwards while posterior surface is smooth. A rough oval impression is present on the medial end of the inferior surface. A longitudinal subclavian groove is present at the lateral half of this surface. At the lateral end of the groove, nutrient foramen lies which runs in a lateral direction.[1] The nutrient artery is derived from the supraclavicular or clavicular branch of thoracoacromial artery.[4] When the nutrient foramina are absent in the clavicle, the blood supply is from the periosteal network.[5]

A bone is supplied by a nutrient artery which passes through the small tunnel called as a nutrient foramina or neurovascular foramina. During active growth period of the long bone the principle source of blood is the nutrient artery.[5] Berard in 1835 was the first to correlate the direction of the nutrient canals with the mode of bone's ossification and growth.[6] The variations in direction of the nutrient foramina in long bones were first explained by Humphrey in 1861. He suggested that position of the nutrient artery and direction of its canals are determined by the interaction of interstitial growth of periosteum and oppositional growth of bone.[7]

The topographical knowledge of the nutrient foramen is important in orthopaedic procedures like nail plating, K wire fixation, reduction, internal fixation devices for the treatment of fracture, coracoclavicular ligament repair and in free vascularized bone graft to preserve the circulation[2,8] as the periosteal and endosteal blood supply with good anastomosis is essential for ideal bone graft.[9]

The study was undertaken to analyse nutrient foramina in adult human clavicles in relation to their number, position, direction, and distribution over bone length.

METHODS

A cross sectional study was carried out in the Anatomy department of Jawaharlal Nehru Medical college, Sawangi (M), Wardha, from, October 2019 to September 2020 after obtaining IEC (Institutional Ethical Committee) clearance. As per the literature available, we included 67 adult dry human clavicles (31 right sides and 36 left sides) of unknown age and sex, without any pathological changes, deformity, or fracture in the present study. Number, position, and direction of the nutrient foramina were observed by using a magnifying lens. We have identified the nutrient foramina by the presence of a well-marked groove leading to the foramen.

The number, topography, and direction of the neurovascular foramina in relation to borders or surfaces of the shaft were analysed. The nutrient foramina within 1 mm from any border were considered lying on that border. To confirm patency of the nutrient foramina a needle was passed through each foramen. The total length of the clavicles and the distance of foramina from the sternal end were measured in millimetres by using digital vernier caliper, ignoring curves of clavicles.

Each clavicle was divided into three equal regions i.e.; medial 1 / 3rd, middle 1 / 3rd and lateral 1 / 3rd and the location of the foramen was noted. The foramina were topographically classified into 1 / 3 regions (medial 1 / 3, middle 1 / 3 and lateral 1 / 3).

Hughes formula : $FI = \frac{(DNF}{TL)} x\ 100$

was applied to calculate the foramina index. DNF = The distance from the proximal end (sternal end) of the clavicle to the nutrient foramen. TL = total length of clavicle.[10]

Statistical Analysis

Statistical analysis was done by chi square test. Software SPSS 24.0 version and Graph Pad Prism 7.0 V was used.

RESULTS

No. of Nutrient Foramina	Right (N = 31)	Left (N = 36)	Total (N = 67)	X2 - Value
1	21 (67.74 %)	23 (63.89 %)	44 (65.67 %)	
2	10 (32.26 %)	12 (33.33 %)	22 (32.84 %)	0.90
3	00	01 (2.78 %)	01 (1.49 %)	P = 0.63,NS

Table 1. No. of Nutrient Foramina

The nutrient foramina were observed in all 67 (100 %) clavicles. In 44 (65.67 %) single foramen and in 22 (32.84 %) double foramina were present. Most of the right clavicles contained single foramen 21 (67.74 %). Three foramina were present in only one clavicle of left side. The number of nutrient foramina on both the sides was found statistically insignificant. (Table 1).

Side of the Clavicle	Medial 2 / 3rd				Lateral 1 / 3rd		Total no. of Nutrient Foramina
	Anterior	Posterior	Superior	Inferior	Superior	Inferior	
Right	-	30 (32.97 %)	-	09 (9.89 %)	1 (1.10 %)	1 (1.10 %)	41 (45.06 %)
Left	-	32 (35.16 %)	-	18 (19.78 %)	-	-	50 (54.94 %)
Total	-	62 (68.13 %)	-	27 (29.67 %)	1 (1.10 %)	1 (1.10 %)	91 (100 %)
X2-value	4.21, P-value = 0.23,NS, P > 0.05						

Table 2. Location of Nutrient Foramina on the Surfaces

Total number of nutrient foramina observed was 91. Out of which, 10 (10.98 %) were present on the inferior surface of the right clavicle. Of these 09 (9.89 %) were on medial 2 / 3rd and 1 (1.10 %) on lateral 1 / 3rd of right side clavicle. Right sided clavicle had 30 (32.97 %) and 1 (1.10 %) nutrient foramina on posterior and superior surfaces respectively. 32 (35.16 %) and 18 (19.78 %) nutrient foramina were present on posterior and inferior surfaces of left side respectively. The location of nutrient foramina on the surfaces of both the sides was found statistically insignificant. (Table 2)

Parts of Clavicle	Number of Nutrient Foramina	Number of Clavicles	X2 - Value
Medial 1 / 3rd	20 (21.98 %)	17 (25.37 %)	0.58 P = 0.74,NS
Middle 1 / 3rd	66 (72.52 %)	45 (67.17 %)	
Lateral 1 / 3rd	05 (5.50 %)	05 (7.46 %)	
Total	91 (100 %)	67 (100 %)	

Table 3. Length Wise Distribution of Nutrient Foramina

20 (21.98 %) foramina were present on the medial 1 / 3rd region, 66 (72.52 %) on the middle 1 / 3rd region and 05 (5.50 %) on lateral 1 / 3rd region respectively. Maximum foramina were present in middle 1 / 3rd of the clavicle i.e. 66 (72.52 %). The length wise distribution of nutrient foramina on the surfaces of both sides was found statistically insignificant. (Table 3)

All the nutrient foramina were directed towards acromial end, i.e. away from the growing end. Mean length of the clavicle of right and left side was found 133.1 ± 0.67 mm and 135.6 ± 0.5 mm respectively. DNF of right and left clavicle was 63.2 ± 1.21 mm and 62.8 ± 0.62 mm respectively. Foramina index (FI) was 47.48 mm and 46.31 mm of right and left side clavicle respectively.

DISCUSSION

The external opening of the neurovascular canal is the nutrient foramen and it has a particular position in each bone. The role of nutrient foramina is the growth of the bone and to provide nutrition, the term "Nutrient" itself apprehends it.[11]

In the present study nutrient foramina were present in 67 (100 %) clavicles. Murlimanju BV et al.[9] Rai R et al.[12] Tanna N et al.[13] and Sahu S et al.[14] also observed presence of nutrient foramina in each clavicle while other authors found absence of nutrient foramina in clavicles. Some authors reported that clavicles are supplied by the periosteal arteries, when there is absence of nutrient foramina. Knudsen et al.[15] reported that the periosteal artery becomes the sole source of blood supply in the bones in which the nutrient foramina is absent.

Researchers	Number of Nutrient Foramina				
	0	1	2	3	More Than 3
Murlimanju BV et al. (2014)[9]	-	38.5 %	44.2 %	13.4 %	-
Rai R et al. (2014)[12]	-	42.5 %	52.5 %	5 %	-
TannaN et al. (2015)[13]	-	21 (42 %)	26 (52 %)	0	-
Sowmiya G et al (2016)[5]	7 (6.4 %)	80 (72.7 %)	18 (16.4 %)	4 (3.6 %)	1 (0.9 %)
Sahu S (2017)[14]	-	23 (43.38 %)	27 (50.93 %)	3 (5.65 %)	
Joshi P et al. (2018)[16]	3 (6 %)	34 (68 %)	13 (26 %)	0	
Rekha et al. (2019)[8]	4.7 %	36.5 %	28.3 %	4.7 %	
Kumar D et al. (2019)[2]	9.80 %	73.52 %	14.70 %	1.96 %	
Present study (2020)	-	44 (65.67 %)	22 (32.84 %)	01 (1.49 %)	

Table 4. Comparison of Number of Nutrient Foramina with Different Researchers

Joshi P et al.[16] observed single foramen in 34 (68 %) while we found 44 (65.67 %) clavicles having single foramen which is in concurrence with our study. In the present study double foramina were present in 22 (32.84 %) clavicles while Rai R et al.[12] TannaN et al.[13] and Sahu S[14] in their study observed more than 50 % clavicles had double foramina. Three foramina were present in only one clavicle of left side in the present study. Sowmiya G et al.[5] observed 1 (0.9 %) clavicle having three foramina. Patake SM and Mysorekar VR (1977)[5] opined that there is no significant relation between the number of foramina to the bone. They also described that the number of ossification centres may not have relation with the number of foramina, as the clavicle generally has a single foramen but has two primary centres while the femur usually has two foramina but has one primary centre of ossification.

Researchers	Location of Nutrient Foramina			
	Inferior	Posterior	Superior	Anterior
Murlimanju BV et al. (2014)[9]	55.8 %	69.2 %	1.9 %	-
Rai R et al. (2014)[12]	23 (35.4 %)	23 (42.6 %)	-	-
Tanna N et al. (2015)[13]	30 (36.6 %)	52 (63.4 %)	-	-
Sowmiya G et al. (2016)[5]	34 (30.9 %)	80 (72.7 %)	6 (5.4 %)	
Sahu S (2017)[14]	31 (36.9 %)	53 (63.1 %)	-	-
Joshi P et al. (2018)[16]	8 (16 %)	38(76 %)	1 (2 %)	-
Rekha et al. (2019)[8]	39 (62.9 %)	21 (33.8 %)	-	1 (3.22 %)
Kumar D et al. (2019)[2]	14.13 %	85.86 %	-	-
Present study (2020)	28 (30.77 %)	62 (68.13 %)	1 (1.10 %)	-

Table 5. Comparison of Position of Nutrient Foramina in Relation to the Surfaces According to Different Researchers

In the present study total number of nutrient foramina observed was 91. We observed 62 (68.13 %) foramina on the posterior surface. In the study conducted by TannaN et al.[13] Sowmiya G et al.[5] Sahu S[14] Joshi P et al.[16] and Kumar D et al.[2] their findings suggest that nutrient foramina are more common on the posterior surface. Rekha et al.[8] observed 1 (3.22 %) foramen on the anterior surface. Murlimanju BV et al.[9] Sowmiya G et al.[5] Joshi P et al.[16] found 1.9 %, 6 (5.4 %), 1 (2 %) nutrient foramina on the superior surface respectively, while in our study 1 (1.10 %) neurovascular foramen was present on the superior surface. The nutrient foramina are occupied by the vessels that are involved in the initial invasion of the ossifying cartilage which is generally agreed.[9] The position of nutrient foramina is affected by the factors like bone remodelling and the growth rates of two ends of the shaft.[12]

In our study we observed 66 (72.52 %) nutrient foramina at the middle 1 / 3rd region of the clavicle. Murlimanju BV et al.[9] Rai R et al.[12] Tanna N et al.[13] Sowmiya G et al.[5] and Joshi P et al.[16] found maximum number of foramina on the middle 1 / 3rd of the clavicle. While Rekha et al.[8] in their study observed 4 (66.6 %) nutrient foramina on the lateral 1 / 3rd of the clavicles. The relation of the length of clavicle to the location of nutrient foramina is of great clinical importance as the clavicle is commonly fractured at the junction of its two curvatures which is the weakest point of the bone by falling on the outstretched hand.[1]

Researchers	Location of Nutrient Foramina		
	Medial 1 / 3rd	Middle 1 / 3rd	Lateral 1 / 3rd
Murlimanju BV et al. (2014)[9]	9.6 %	92.3 %	1.9 %
Rai R et al. (2014)[12]	10 (15.4 %)	48 (73.8 %)	7 (10.8 %)
Tanna N et al. (2015)[13]	15 (18.3 %)	59 (72 %)	8 (9.8 %)
Sowmiya G et al. (2016)[5]	13 (11.8 %)	100 (90.9 %)	7 (6.3 %)
Sahu S (2017)[14]	16 (19.04 %)	60 (71.42 %)	8 (9.52 %)
Joshi P et al. (2018)[16]	1 (2 %)	46 (88.46 %)	-
Rekha et al. (2019)[8]	7 (19 %)	10 (33.3 %)	4 (66.6 %)
Kumar D et al. (2019)[2]	---	---	---
Present study (2020)	20(21.98 %)	66 (72.52 %)	05 (5.50 %)

Table 6. Comparison of Position of Nutrient Foramina in Relation to the Length of the Clavicle According to Different Researchers

Researchers	Direction of Nutrient Foramina	
	Towards Sternal End	Towards Acromial End
Murlimanju BV et al. (2014)[9]	---	100 %
Rai R et al. (2014)[12]	---	100 %
Tanna N et al. (2015)[13]	---	100 %
Sowmiya G et al. (2016)[5]	5 (4.8 %)	98 (95.1 %)
Sahu S (2017)[14]	---	100 %
Joshi P et al. (2018)[16]	----	----
Rekha et al. (2019)[8]	4.79 %	90.47 %
Kumar D et al. (2019)[2]	---	100 %
Present study (2020)	------	100 %

Table 7. Comparison of Direction of Nutrient Foramina According to Different Researchers

In our study, we observed that all the nutrient foramina were directed towards the acromial end. In the study conducted by the Murlimanju BV et al.[9] Rai R et al.[12] Tanna N et al.[13] Sahu S,[14] Joshi P et al.[16] and Kumar D et al.[2] observed that all the nutrient foramina were directed towards the acromial end. Sowmiya G et al.[5] and Rekha et al.[8] found 5 (4.8 %) and 4.79 % of nutrient foramina directed towards the sternal end respectively. Lacroix P proposed that the certain abnormal nutrient foramina directions are due to the pull of muscle attachments on periosteum.[9] Many authors have put the theories that explain the directions of the normal and abnormal nutrient foramina. In the literature, vascular theory of Hughes and the "periosteal slip'' theory of Schwalbe are widely accepted.[12] Longia GS et al. commented that all reported normal and abnormal nutrient canals are best explained by the vascular theory.[16]

In our study, mean length of the clavicle of right and left side was found 133.1 ± 0.67 mm and 135.6 ± 0.5mm respectively. DNF of right and left clavicle was 63.2 ± 1.21 mm and 62.8 ± 0.62 mm respectively. Foramina index (FI) was 47.48 mm and 46.31 mm of right and left side clavicle respectively. Sahu S et al.[14] in their study found average length of clavicle as 126.38 mm, DNF 65.8 mm, and foramina index 52.06 respectively which is in concordance with our study.

CONCLUSIONS

The knowledge of number, location, and direction of nutrient foramina is useful for surgeons performing surgical procedures like internal fixation, coracoclavicular ligament repair, transplant techniques and bone grafting. The clinical knowledge of the nutrient foramina and its variations are important, as the microvascular bone transfer is becoming more popular where preservation of the circulation of affected bone is of vital importance for facilitating graft healing in the recipient.

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