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MORPHOMETRIC ANALYSIS OF THE VARIATIONS IN THE NUMBER, POSITION, AND DIRECTION OF NUTRIENT FORAMEN IN THE CLAVICLE

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Abstract
Background: The clavicle is a horizontally positioned, bent, and modified long bone located at the base of the neck. It transfers the force exerted by the upper limb to the axial skeleton. **Aim:** Morphometric analysis of the variations in the number, position, and direction of nutrient Foramen in the clavicle. **Materials and Methods:** This research, classified as an analytical observational study, examined 60 dry humeri (30 right and 30 left) of unknown genders collected from the department of anatomy. This investigation eliminated bones that had previous fractures that had healed, congenital abnormalities, and substantial pathological alterations. Side determination was performed on all humeri. The nutrient foramina were identified by the presence of a distinct groove that leads to the foramen. The nutritional foramen of every humeri was examined to determine the quantity, position, location, and orientation. **Results:** Three (3.33%) of the humerus specimens lacked nutrient foramina. A solitary nutrient foramen was detected in 28 (46.67%) of the right humerus, 27 (45%) of the left humerus, and 55 (91.67%) of the whole humerus. Two nutrient foramina were detected in 1 (1.33%) of the right humerus, 1 (1.33%) of the left humerus, and 2 (3.33%) of the whole humerus. Only one (1.67%) of the left humerus specimens showed the presence of three nutrient foramen. Among the total of 60 nutritional foramina, 88.33% were located on the anteromedial surface, 86.67% on the right side, and 90% on the left side. Out of all the nutritional foramen, 10% were located on the anterolateral surface, with an equal distribution of 10% on the right side and 10% on the left side. The posterior surface included 1.67% of the nutritional foramen, with 3.33% located specifically on the right side. Out of a total of 60 nutrient foramen, the maximum number was observed in the middle one-third of the shaft (86.67%), followed by the distal third (13.33%). No nutrient foramen was found on the proximal one-third of the shaft. **Conclusion:** The position of the nutritive foramen of the humerus was variable, perhaps appearing on the anteromedial, anterolateral, or posterior sides. Likewise, it may occur on the middle or lower part of the humerus bone.

INTRODUCTION

The clavicle is a horizontally positioned modified long bone located at the base of the neck, which is well recognised. It is subcutaneous over its whole length. The clavicle serves as a conduit for transferring the weight of the upper limb to the axial skeleton. The clavicle has two extremities, namely lateral and medial, along with a cylindrical shaft.[1] The shaft is split into a lateral one-third and a medial two-thirds. The upper portion of the shaft is compressed horizontally, resulting in a flattened shape. The object has dual boundaries, namely the anterior and posterior borders, together with two planes, the superior and inferior surfaces. The front edge is concave, whereas the back edge is convex. The uppermost layer is located under the skin. The lower surface has a raised area. The anatomical structures in question are referred to as the conoid tubercle and the trapezoid ridge. The middle two-thirds of the shaft is curved and has four sides. The front surface is curved outward, while the back surface is flat. The upper surface is smooth in its middle section, whereas the lower surface has a rough oval indentation in its middle section. The subclavian groove is located on the lateral third of the inferior surface.[2] The nutritional artery traverses via the nutrient foramen, which is the most sizable opening on the diaphysis of long bones.[3] This artery supplies the bulk of blood to long bones throughout their active development and the first stages of ossification. In pathological circumstances such as developmental defects, acute haematogenic osteomyelitis, and fracture repair, the nutritional artery serves as the primary blood supply to bones.[4,5] The nutritious artery, originating from the suprascapular artery, is located laterally to the laterally directed subclavian groove and goes via the nutrient foramen at the intersection of the middle and lateral third of the clavicle. The position and quantity of nutrition foramina in long bones are not constant.[6-8] A nutritive foramen is located at the lateral end of the subclavian groove, travelling in a lateral direction.[9] However, a research has indicated that the clavicle is exclusively fed by periosteal arteries, and the presence of a nutritional artery is absent.[10] Conversely, the nutritional foramina of the clavicle has clinical significance. These structures are implicated in the healing process of clavicular fractures, which may lead to neurovascular complications such as supraclavicular nerve entrapment syndrome and brachial plexus damage. Traditionally, it was believed that most clavicular fractures heal and result in favourable functional results. The nonoperative therapy is now obsolete. A recent study has shown that some subgroups of individuals with these injuries had a greater incidence of nonunion and particular impairments in shoulder function.[11] As a result, orthopaedic techniques such as nail plating, K wire fixation, and more recently microsurgical vascularized bone transplantation have gained significant popularity. The understanding of the nutrient foramen is crucial in surgical techniques such as bone grafting and microsurgical vascularized bone transplantation. Currently, these strategies are quite popular. The anatomical description of these foramina is crucial for maintaining the circulation of the afflicted bony tissue. This is especially important for orthopaedic surgeons who perform surgical procedures where maintaining the patency of artery flow is vital in order to facilitate fracture repair.[12] he presence of a sufficient blood flow is crucial in free vascular bone transplantation. In order to enhance the healing of fractures, maintain a sufficient blood supply for the survival of osteoblast and osteocyte cells, and assist the healing of grafts in the recipient, preservation is necessary.[13] Understanding the anatomical details of the nutritional foramen of the clavicle is crucial for maintaining proper blood flow to the damaged bone.

MATERIALS AND METHODS

This research, classified as an analytical observational study, examined 60 dry humeri (30 right and 30 left) of unknown genders collected from the department of anatomy. This investigation eliminated bones that had previous fractures that had healed, congenital abnormalities, and substantial pathological alterations. Side determination was performed on all humeri. The nutrient foramina were identified by the presence of a distinct groove that leads to the foramen. The nutritional foramen of every humeri was examined to determine the quantity, position, location, and orientation. The nutrient foramen was spotted using a magnifying lens. The humerus exhibits many nutrient foramina, and among them, the bigger one is referred to as the dominant foramen, while the smaller one is known as the secondary foramen. The position of the nutrient foramen was determined by the foraminal index (FI) using the following formula: FI = DNF/TL x 100. Where DNF is the distance of nutrient foramen from the most proximal part of the humerus and TL is the total length of the humerus.

The location of the nutrient foramen was categorised into three types based on the FI value: type 1 = FI < 33.33, where the foramen is situated in the upper third of the humerus; type 2 = FI between 33.33 and 66.66, where the foramen is situated in the middle third of the humerus; type 3 = FI > 66.66, where the foramen is situated in the lower third of the humerus.

The osteometric board was used to measure the overall length of humeri in centimetres. The distance between the nutritional foramen and the closest point on the humerus was measured using a digital vernier calliper, with the measurement recorded in centimetres. The data collected was recorded and subjected to statistical analysis using a Microsoft Excel spreadsheet.

RESULTS

Three (3.33%) of the humerus specimens lacked nutrient foramina. A solitary nutrient foramen was detected in 28 (46.67%) of the right humerus, 27 (45%) of the left humerus, and 55 (91.67%) of the whole humerus. Two nutrient foramina were detected in 1 (1.33%) of the right humerus, 1 (1.33%) of the left humerus, and 2 (3.33%) of the whole humerus. Only one (1.67%) of the left humerus specimens showed the presence of three nutrient foramen, as seen in. [Table 1]

A total of 60 nutritional foramina were observed on the anteromedial, anterolateral, and posterior surfaces. Among the total of 60 nutritional foramina, 88.33% were located on the anteromedial surface, 86.67% on the right side, and 90% on the left side. Out of all the nutritional foramen, 10% were located on the anterolateral surface, with an equal distribution of 10% on the right side and 10% on the left side. The posterior surface included 1.67% of the nutritional foramen, with 3.33% located specifically on the right side. The nutritional foramina had a downhill orientation, as seen in. [Table 2]

The incidence of nutrient foramina in relation to different parts of the shaft of the humerus was described in the proximal one-third, middle one-third, and distal one-third. Out of a total of 60 nutrient foramen, the maximum number was observed in the middle one-third of the shaft (86.67%), followed by the distal third (13.33%). No nutrient foramen was found on the proximal one-third of the shaft. The

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observation revealed that all nutrition foramina were oriented downwards and towards the distal end of the humerus, specifically away from the developing end. [Table 3]

The humerus length measurements were determined to be 29.98 ± 1.14 cm in the right arm, 30.21 ± 1.36 cm in the left arm, and 30.09 ± 1.25 cm in both arms combined. The average distance from the proximal end of the humerus to the nutritional foramen was determined to be 16.59 ± 1.34cm in the right humerus, 16.62 ± 1.17 cm in the left humerus, and 16.60 ± 1.25cm in both humeri combined. The foraminal index was determined to be 56.67% in the right humerus, 56.67% in the left humerus, and 56.67% in the combined total of both humeri. [Table 4]

Table 1: Number of the nutrient foramen of the humerus

	Right		Left		Total	
No. of nutrient foramen	**Number**	**%**	**Number**	**%**	**Number**	**%**
0	1	1.67	1	1.67	2	3.33
1	28	46.67	27	45	55	91.67
2	1	1.67	1	1.67	2	3.33
3	0	0	1	1.67	1	1.67

Table 2: Location of the nutrient foramen

Surface	Right		Left		Total	
	Number	**%**	**Number**	**%**	**Number**	**%**
Anteromedial	26	86.67	27	90	53	88.33
Posterior	1	3.33	0	0	1	1.67
Anterolateral	3	10	3	10	6	10

Table 3: Site of the nutrient foramen

Situation	Right		Left		Total	
	Number	**%**	**Number**	**%**	**Number**	**%**
Proximal 1/3	0	0	0	0	0	0
Middle 1/3	25	83.33	27	90	52	86.67
Distal 1/3	5	16.67	3	10	8	13.33

Table 4: Length of the humerus, the distance of nutrient foramina from the proximal end, and the foraminal index

Parameter	Right	Left	Total
Mean total length (cm)	29.98 ± 1.14	30.21 ± 1.36	30.09 ± 1.25
Distance of nutrient foramina from the proximal end (cm)	16.59 ± 1.34	16.62 ± 1.17	16.60 ± 1.25
Foraminal index	56.67%	56.67%	56.67%

DISCUSSION

During the period of vigorous development of long bones, the nutritional artery serves as the primary supplier of blood. Berard (1835),[14] was the first to explain the association between the orientation of the nutrition canal and the process of ossification and development of bone. The humerus is additionally supplied with blood via metaphyseal and periosteal arteries, which originate from the axillary and brachial arteries. Orthopaedic surgeons performing open reduction of fractures must possess a thorough understanding of the many variations of the nutritional foramen. This information is crucial in order to prevent harm to the nutrient artery, hence reducing the risk of delayed union or nonunion of the fracture. An uninterrupted blood flow to the bone is crucial for the proper healing of a broken bone. The occurrence of delayed union or nonunion of a bone fracture is well recognised to be caused by insufficient vascular supply. Table 5 presents a comparison of the occurrence of the nutrient foramen. [Table 5]

The current investigation demonstrated that a solitary nutrient foramen was seen in 91.67% of humeri. Laing (93%),[15] and Bhatnagar et al. (90%),[16] also observed a same result in their research. Several investigations have shown a reduced occurrence of a single nutrient foramen,[17,18] Joshi et al,[18] and Arfan et al,[17] found that only 63% and 60.40% of humerus bones, respectively, had a single nutrition foramen. The current investigation revealed that the occurrence of double nutrient foramen was seen in 3.33% of humeri, a rate that closely aligns with the findings of Laing (7%),[15] and Bhatnagar et al. (7.14%).[16] Joshi et al,[18] discovered that 33% of humeri had a greater occurrence of a twin nutrient foramen. The majority of writers noted the existence of triple nutritional foramina in humeri.[18,19] The current research noted that a triple nutrient foramen was discovered in 1.67% of humeri, a percentage that closely aligns with the findings of previous studies conducted by Halagatti and Rangasubhe (2%),[19] and Bhatnagar et al. (1.43%).[16] This research found that 3.33% of humeri lacked a nutritional foramen, which is consistent with the findings of Ramya Sree et al,[20] who reported a similar occurrence of 3.67% of humeri being fed by periosteal arteries in such situations (Table 5).[21]

The nutritional foramen is situated on the anteromedial aspect of the humeral shaft in close proximity to the medial border, but its precise placement may vary. 88.33% of the foramina were located on the anteromedial surface, which aligns with the results reported by Chandrasekaran et al. (89.92%),[22] and Mansur et al. (88.86%).[23] Conversely, a research conducted in Pakistan by Khan et al,[24] found that a greater proportion (96%) of nutritional foramina were located on the anteromedial surface, as seen in. [Table 6]

The current research found that 86.67% of nutritional foramina were situated in the middle one-third of humeri, whereas 13.33% were positioned in the distal one-third. The proximal one-third of the humerus did not exhibit any nutrition foramina. This discovery aligns with the results reported by Chandrasekaran et al,[21] as shown in. [Table 7]

Table 5: Comparison of number of the nutrient foramen

Authors	0	1	2	3	No. of humerus
Laing et al.[15]	NA	28 (93%)	2 (7%)	NA	30
Bhatnagar et al.[16]	1 (1.43%)	63 (90%)	5 (7.14%)	1 (1.43%)	70
Arfan et al.[17]	4 (4.65%)	52 (60.40%)	25 (29.06%)	5 (5.81%)	86
Joshi et al.[18]	NA	126 (63%)	66 (33%)	8 (4%)	200
Halagatti and Rangasubhe.[19]	NA	161 (80.5%)	35 (17.5%)	4 (2%)	200
Ramya Sree et al.[20]	8 (3.67%)	169 (81.19%)	40 (18.35%)	1 (0.45%)	218
Chandrasekaran et al.[22]	NA	198 (76.74%)	53 (20.54%)	7 (2.71%)	258
Mansur et al.[23]	NA	154 (60.87%)	73 (28.85%)	16 (6.32%)	253
Present study	2 (3.33-%)	55 (91.67%)	2 (3.33%)	1 (1.67%)	60

Table 6: Comparison of the location of the nutrient foramen

Author	No. of humerus	Anteromedial surface	Posterior surface	Anterolateral surface
Mansur et al.[23]	253	88.86%	6.52%	4.62%
Chandrasekaran et al.[22]	258	89.92%	8.53%	1.55%
Yaseen et al.[25]	100	88.50%	8.53%	3.50%
Khan et al.[24]	75	96%	2.67%	1.33%
Present study	60	88.33%	1.67%	10%

Table 7: Comparison of the site of the nutrient foramen

Author	No. of humerus	Proximal 1/3rd	Middle 1/3rd	Distal 1/3rd
Arfan et al.[17]	86	4.87%	91.46%	3.65%
Chandrasekaran et al.[22]	258	NA	86.43%	13.57%
Mansur et al.[23]	253	0.54%	94.84%	4.62%
Yaseen et al.[25]	100	NA	89%	11%
Present study	60	NA	86.67%	13.33%

CONCLUSION

The position of the nutritive foramen of the humerus was variable, perhaps appearing on the anteromedial, anterolateral, or posterior sides. Likewise, it may occur on the middle or lower part of the humerus bone. Understanding the nutritional foramen of the clavicle is crucial in clinical settings when doing vascularized bone grafting to ensure the preservation of blood supply to the graft.

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