

# Morphological and Morphometric Evaluation of Clavicular Nutrient Foramina in Dry Bones: A Cross-sectional Study from Haryana, India

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## ABSTRACT

**Introduction:** Nutrient foramina play a critical role in supplying blood to the clavicle, and their variations are of clinical significance in orthopaedic and reconstructive surgeries. However, limited data are available on their morphology and distribution in the Indian population.

**Aim:** To analyse the number, location, direction, and foraminal index of nutrient foramina in adult human clavicles.

**Materials and Methods:** A cross-sectional study was conducted on 100 dry adult human clavicles (50 right, 50 left) of unknown age and gender from the Department of Anatomy, SGT University, Gurugram, Haryana, India from May 2025 to September 2025. Each clavicle was examined for the presence, number, location and direction of nutrient foramina. Morphometric parameters, including clavicular length, distance of foramina from the sternal end, and foraminal index, were measured using a digital Vernier calliper.

**Results:** Nutrient foramina were present in 98% of clavicles 49/50 on each side single foramina predominated 31 (63.3% left, 69.4% right), followed by double 13 (26.5% both sides) and triple 5 (10.2% left, 4.1% right). Most foramina were located in the middle third 43 (84.3% left, 84.3% right), followed by the lateral third 6 (11.8% left, 7.8% right) and the medial third 2 (3.9% left, 7.8% right). The majority (99%) of foramina were directed towards the acromial end. The mean clavicle length was 135.27 mm, the mean distance of foramina from the sternal end was 72.96 mm, and the mean foraminal index was 53.95. Most foramina were located in the middle third and commonly situated on the posterior surface (67%), followed by the inferior surface (39%).

**Conclusion:** The clavicle typically contains a single nutrient foramen, situated in the middle third on the posterior surface and directed laterally.

**Keywords:** Clavicle, Foraminal index, Nutrient foramina, Segmental location, Variations

## INTRODUCTION

A modified long bone of the pectoral girdle, the clavicle is a subcutaneous, sinuous structure that sits horizontally at the base of the neck. The scapula is held laterally by it, acting as a strut, allowing the upper limb to swing freely from the side of the trunk. It also has a vital biomechanical function by transferring forces from the upper limb to the axial skeleton through the medial two-thirds of the shaft and the coracoclavicular ligament [1,2]. Anatomically, the clavicle is made up of a shaft with two ends: the acromial (lateral) and sternal (medial). Usually orientated laterally, a nutrient foramen is located close to the lateral end of the subclavian groove, which lies on the inferior surface of the shaft. This foramen frequently conveys the medial supraclavicular nerve and the nutritive artery, which is typically generated from the suprascapular artery [3]. During active growth, the main circulatory supply to long bones is the nutritional artery. Humphrey later proposed the periosteal sliding theory, which posits that differential periosteal growth explains the canal's orientation toward the slower-developing end. Berard was the first to link the direction of nutrient canals with bone ossification patterns [2,3]. In orthopaedic and surgical operations, such as bone grafting and microsurgical vascularised bone transplantation, where maintaining the intraosseous blood supply is crucial for osteocyte viability and graft survival, such in-depth anatomical knowledge is crucial [4,5]. The clavicle's nutritional foramen is still little described in the literature, despite its clinical significance. Therefore, the present study aimed to analyse the number, location, direction, and foraminal index of nutrient foramina in adult human clavicles.

## MATERIALS AND METHODS

This cross-sectional study was performed on 100 adult dry human clavicles (50 right-sided, 50 left-sided) of unknown age and gender.

Specimens were obtained from the Department of Anatomy at SGT University, Budhera, Gurugram, Haryana, India in five months from May 2025 to September 2025. The study was approved by the Institutional Ethical Committee of SGT University (Approval No.IEC/PhD/2025-02).

**Inclusion and Exclusion criteria:** Fully ossified clavicles without evidence of fractures, healed malunions, or macroscopic lytic/sclerotic lesions were included and clavicles showing damage or periosteal alterations obscuring nutrient foramina were excluded from the study.

**Sample size:** A total of 100 clavicles (50 right, 50 left) fulfilling the inclusion criteria were included in the study. The sample size was determined based on the availability of specimens during the study period and in accordance with previously published morphological studies.

### Study Procedure

A detailed morphological and morphometric examination was carried out. Bones were cleaned and visually inspected; regions of interest on the shaft were examined. To verify patency, a 24gauge needle was gently inserted through each identified nutrient foramen. The recorded parameters were as follows:

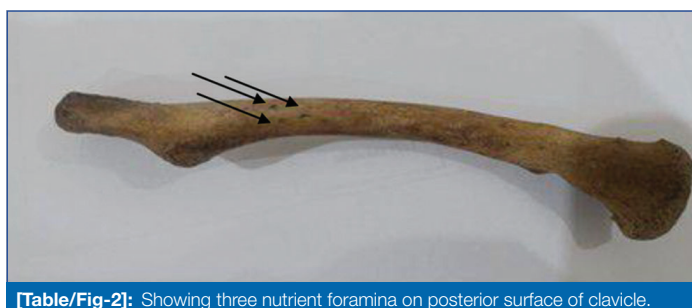
- Presence:** Whether at least one nutrient foramen was observable per clavicle;
- Number of foramina:** Number of foramina: classified as single, double, or multiple ( $\geq 3$  foramina) per bone;
- Location:** The shaft was divided into medial, middle, and lateral thirds based on total length; each foramen was assigned to one of these segments;
- Surface position:** Nutrient foramina were mapped to the anterior, posterior, inferior, or Superior Surface (SS) according

to clavicular anatomy; in some bones, foramina were present on more than one surface;

5. **Direction:** Determined relative to the bone ends and noted as directed towards the sternal or acromial end [Table/Fig-1-4].



[Table/Fig-1]: Showing two nutrient foramina on inferior surface of clavicle.



[Table/Fig-2]: Showing three nutrient foramina on posterior surface of clavicle.



[Table/Fig-3]: Clavicle (left side) showing three nutrient foramina. Anterior surface (black arrow), inferior surface (white arrow), and posterior surface (arrowhead). Scale bar= 1 cm.



[Table/Fig-4]: Showing single nutrient foramina on inferior surface of clavicle.

All measurements were taken twice by the same observer using a digital Vernier calliper with 0.01 mm precision, and the average value was recorded. The observer was blinded to the side of the clavicle during measurement to minimize bias. Intra-observer reliability was assessed using the intra-class correlation coefficient (ICC), which was >0.90 for all parameters.

Morphometric measurements were carried out for following parameters:

- **Total clavicle length (L):** Measured using a digital Vernier calliper along the bone's curvature [Table/Fig-5].
- **Distance from sternal end to foramen (D):** Measured in mm.
- **Foramen Index (FI):** Calculated using Hughes' formula:

$$FI = \text{Distance from sternal end} / \text{Total clavicle length} \times 100$$

All measurements were taken twice by the same observer, and the average value was recorded to minimise intra-observer error.

## STATISTICAL ANALYSIS

Categorical variables were expressed as frequencies and percentages. Comparison between left and right clavicles was performed using the Chi-square test. Continuous variables were



[Table/Fig-5]: Showing the measurement of length of clavicle with digital vernier calliper.

expressed as mean  $\pm$ Standard Deviation (SD), and comparison between sides was carried out using the Independent samples t-test, Confidence Intervals (CIs) for the mean difference were calculated. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using IBM Statistical Pacakge for Social Sciences (SPSS) Statistics version 26.0.

## RESULTS

In some clavicles, more than one nutrient foramen was present. When multiple foramina were located in different segments of the same clavicle, each foramen was recorded separately under its respective segment. For example, if a clavicle had one foramen in the middle third and another in the medial third, it contributed once to each segmental category.

Nutrient foramina were most prevalent in the middle third (84.3% left, 84.3% right), followed by lateral third (11.8% left, 7.8% right) and medial third (3.9% left, 7.8% right), with no significant side differences. The table has been constructed based on the number of cases in which nutrient foramina were present in the middle, medial, and lateral segments of the clavicle [Table/Fig-6].

The posterior surface was the most common site for nutrient foramina on both sides, followed by the inferior surface. Very few foramina were observed on the anterior and SSs. There was no significant difference in surface distribution between left and right clavicles [Table/Fig-7]. A total of 50 clavicles were examined on each side. In five clavicles, nutrient foramina were observed on more than one surface of the same bone. For example, a single clavicle showed a foramen opening on both the posterior and Anterior Surfaces (AS). In such instances, each surface occurrence was recorded separately under the respective surface category.

Therefore, although 50 clavicles were studied per side, the total number of surface observations exceeded the number of bones (Left=55, Right=56; Total=111).

In all 49 (100%) left clavicles and in 48 (98%) right clavicles, the nutrient foramina were directed toward the lateral (acromial) end. However, in one right clavicle (2%), the nutrient foramen was directed medially toward the sternal end. Additionally, one clavicle on each side lacked a nutrient foramen [Table/Fig-8].

Of the 50 left clavicles, one lacked a nutrient foramen. Among the remaining 49 left clavicles, a single foramen was observed in 31 (63.3%), double foramina in 13 (26.5%), and triple foramina in five (10.2%). Of the 50 right clavicles, one lacked a nutrient foramen. Among the remaining 49 right clavicles, a single foramen was observed in 34 (69.4%), double foramina in 13 (26.5%), and triple foramina in two (4.1%) [Table/Fig-9].

Foraminal index of left clavicles was  $54.33 \pm 10.14$  and of right clavicles was  $53.56 \pm 9.71$ , but statistically there was no difference in right and left clavicles foraminal index [Table/Fig-10].

## DISCUSSION

The present study demonstrated that most clavicles possessed a single nutrient foramen, located predominantly on the posterior surface in the middle one-third and ran longitudinally with the shaft.

Nutrient foramina		Side			Chi-Square	p-value
		Left	Right	Total		
		n (%)	n (%)	N (%)		
Segmental Location	Middle 1/3rd	43 (84.3%)	43 (84.30%)	86 (84.30%)	0.66	0.72
	Medial 1/3rd	2 (3.9%)	4 (7.8%)	6 (5.9%)		
	Lateral 1/3rd	6 (11.8%)	4 (7.8%)	10 (9.8%)		
	Total	51 (100.0%)	51 (100.0%)	102 (100%)		

**[Table/Fig-6]:** Segmental distribution of nutrient foramina in left and right clavicles (n=102 foramina).

Surface location	Left clavicles (n=55)	Right clavicles (n=56)	Total (N=111)	Chi-square	p-value
Posterior surface	30 (54.5%)	37 (66.1%)	67 (60.4%)	4.02	0.26
Inferior surface	20 (36.4%)	19 (33.9%)	39 (35.1%)		
Anterior Surface (AS)	3 (5.5%)	0	3 (2.7%)		
Superior Surface (SS)	2 (3.6%)	0	2 (1.8%)		
Total	55 (100%)	56 (100%)	111 (100%)		

**[Table/Fig-7]:** Surface-wise distribution of nutrient foramina based on the number of surface observations, not the number of clavicles.

Direction of foramina		Side			Chi-Square	p-value
		Left	Right	Total		
		n (%)	n (%)	N (%)		
Direction of foramina	Lateral	49 (100.0%)	48 (98.0%)	97 (99.0%)	1.010	0.315
	Medial	0	1 (2.0%)	1 (1.0%)		
	Total	49 (100.0%)	49 (100.0%)	98 (100.0%)		

**[Table/Fig-8]:** Direction of nutrient foramina in right and left clavicles.

No. of nutrient foramen		Side			Chi-square	p-value
		Left	Right	Total		
		n (%)	n (%)	N (%)		
No. of nutrient foramen	One	31 (63.3%)	34 (69.4%)	65 (66.3%)	1.424	0.491
	Two	13 (26.5%)	13 (26.5%)	26 (26.5%)		
	Three	5 (10.2%)	2 (4.1%)	7 (7.1%)		
	Total	49 (100.0%)	49 (100.0%)	98 (100.0%)		

**[Table/Fig-9]:** Number of nutrient foramina in right and left clavicles.

		Side			t-value	p-value
		Left	Right	Total		
		n	n	n		
Distance of NF from sternal end	N	49	49	98	0.601	0.549
	Mean±SD	73.87±15.60	72.04±14.56	72.96±15.04		
	Minimum	41.65	23.23	23.23		
	Maximum	110.64	97.19	110.64		
Length of clavicle (mm)	N	50	50	100	0.808	0.421
	Mean±SD	136.24±12.32	134.29±11.74	135.27±12.01		
	Minimum	99.13	94.60	94.60		
	Maximum	156.21	153.60	156.21		
Foraminal index	N	49	49	98	0.382	0.704
	Mean±SD	54.33±10.14	53.56±9.71	53.95±9.88		
	Minimum	30.35	19.70	19.70		
	Maximum	74.63	72.53	74.63		

**[Table/Fig-10]:** Mean of length of clavicle, distance of NF from sternal end and foraminal index.

With respect to segmental location, the nutrient foramen was predominantly located in the middle one-third of the clavicle on both sides (left: 84.3%, right: 84.3%), representing 86.0% of all foramina observed.

The present study finding supports the concept that the middle third of the clavicle is the principal region for vascular entry, which may be

related to the developmental and biomechanical characteristics of this segment, as the middle third represents the last region to ossify and is subjected to maximum compressive and tensile forces during upper limb movement.

Regarding the surface location, the nutrient foramen was most commonly found on the posterior surface of the clavicle. The prevalence of single nutrient foramina in the present study (66.3%) aligns closely with findings from Joshi P and Mathur S (68%) and Lal et al., (68%) but differs from Saha PK et al., (53.7%) and Tanna N and Tanna V (42%) [6-9] and is comparable to the observations reported by Rai R et al., and Sinha S et al., [10,11] [Table/Fig-11]. This variation may be attributed to regional genetic differences between populations of Eastern India (Saha PK et al.,) and Haryana (present study), or differences in sample size and inclusion criteria. Similarly, the middle third predominance (86.0%) is consistent with the range reported in the literature (70.58% to 94.44%), though lower than the 94.44% reported by Prabhu SP et al., [12] in the Goan population, suggesting possible ethnic variation in clavicular vascular patterning [2,6,8,10,11,12] [Table/Fig-12].

The consistent location of the nutrient foramen in the middle third of the clavicle, particularly on its posterior surface, has direct clinical relevance. Surgeons performing plate osteosynthesis for mid-shaft clavicle fractures should exercise caution while exposing the posterior surface to preserve the dominant intraosseous blood supply, potentially reducing the risk of non union. The mean foraminal index of 53.95 indicates that the vascular entry point lies just lateral to the midpoint, guiding safe zones for surgical dissection [1,2,7,8,10,11,12] [Table/Fig-13].

No. of foramina	Saha PK et al., (54 clavicles) [6]	Sahu S and Meher D (53 clavicles) [2]	Joshi P and Mathur S (50 clavicles) [7]	Tanna N and Tanna V (50 clavicles) [8]	Lal N et al., (50 clavicles) [9]	Rai R et al., (40 clavicles) [10]	Sinha S et al., (50 clavicles) [11]	Prabhu SP et al., (70 clavicles) [12]	Present study (100 clavicles)
1	53.70%	43.38%	68%	42%	68%	42.5%	70%	57.14%	66.3%
2	40.74%	50.93%	26%	52%	26%	52.5%	24%	32.85%	26.5%
3	5.56%	5.65%	-	6%	-	5%	6%	8.57%	7.1%
4	-	-	-	-	-	-	-	1.42%	
Absent	-	-	6%	-	6%	-	-	-	2%

**[Table/Fig-11]:** Comparison of no. of nutrient foramina with previous studies. foraminal index.

Position of foramen	Sahu S and Meher D [2]	Tanna N and Tanna V [8]	Saha PK et al., [6]	Rai R et al., [10]	Sinha S et al., [11]	Prabhu SP et al., [12]	Present Study
Medial 1/3	19.04%	18.3%	17.07%	15.4%	10.29%	4.62%	6.0%
Lateral 1/3	9.52%	9.8%	8.53%	10.8%	19.11%	0.92%	10.0%
Middle 1/3	71.42%	72%	74.39%	73.8%	70.58%	94.44%	86.0%

**[Table/Fig-12]:** Comparison of position of nutrient foramina with previous studies.

Mean foraminal index	Sowmiya G et al., [1]	Sahu SK and Meher D [2]	Joshi P and Mathur S [7]	Tanna N and Tanna V [8]	Rai R et al., [10]	Sinha S et al., [11]	Prabhu SP et al., [12]	Present Study
	47.31	52.06	49.76	49.01	48.01	52.25	51.54	53.95

**[Table/Fig-13]:** Comparison of mean of foraminal index with previous studies.

## Limitation(s)

The present study has certain limitations. First, the age and sex of the clavicles were unknown, precluding analysis of demographic variations in foraminal patterns. Second, the sample was confined to a single geographical region (Haryana), which may limit generalisability to other Indian populations. Third, while measurements were taken twice to minimise error, inter-observer variability was not assessed. Finally, as a dry bone study, direct correlation with vascular supply patterns in living individuals could not be established.

## CONCLUSION(S)

In the present series of 100 adult clavicles from Haryana, nutrient foramina were present in the vast majority of bones and most commonly appeared as a single foramen situated in the middle third of the shaft, most commonly on its posterior surface, and directed towards the acromial end. The mean foraminal index placed the foramen just beyond the mid-length of the clavicle, with no significant differences between right and left-sides. These reproducible anatomical patterns provide a practical guide for orthopaedic and reconstructive surgeons aiming to preserve intraosseous blood supply during clavicular fixation and grafting.

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