

An analysis of Morphometric characteristics of Supratrochlear foramen of humerus

Dr. R. Raja Rajeshwari¹, Dr. Dipali Jayesh Trivedi²

¹Assistant Professor, Department of Anatomy, PMCHRI, Chennai

²3rd Year Resident, Department of Anatomy, BJMC, Ahmedabad

Corresponding Author

Dr R. Raja Rajeshwari

Assistant Professor, Department of
Anatomy, PMCHRI, Chennai

Email ID:

rajjeeraj16590@gmail.com

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Abstract:

Background

The supratrochlear foramen (STF) is an anatomical variation located in the distal humerus, formed by the resorption of the septum between the olecranon and coronoid fossae. Its incidence, morphology, and morphometry vary among populations and carry clinical relevance in orthopedic surgeries and radiological interpretations. This study aims to analyze the incidence, shape, and morphometric characteristics of the STF in a central Indian population.

Methods

A descriptive osteological study was conducted on 127 dry, adult human humeri of unknown sex collected from the Department of Anatomy. Each bone was examined for the presence, side, and shape of STF. Measurements were taken using digital vernier calipers to determine distances from anatomical landmarks (medial epicondyle, lateral epicondyle, and lower trochlear margin) and diameters (transverse and vertical) of the STF. In humeri without STF, septal thickness was measured and categorized as opaque or translucent. Data were analyzed using descriptive statistics and unpaired t-tests, with $p < 0.05$ considered significant.

Results

The STF was present in 39 out of 127 humeri (30.7%), more frequently on the left side (33.3%) than the right (28.1%). Among humeri without STF, 51.2% showed an opaque septum and 18.1% had a translucent septum. The most common STF shape was oval (41.0%), followed by round (25.6%) and reniform (12.8%). Morphometric measurements revealed mean distances of 24.8 ± 1.6 mm (right) and 25.1 ± 1.3 mm (left) from the medial epicondyle to the STF, and 4.6 ± 0.8 mm (right) and 4.4 ± 0.9 mm (left) from the lower trochlear margin. The transverse and vertical diameters of the foramen averaged 5.9–6.2 mm and 3.7–3.9 mm, respectively. Septal thickness in humeri without STF averaged 5.1 ± 0.9 mm. No statistically significant side-wise differences were found.

Conclusion

The supratrochlear foramen was present in nearly one-third of humeri in this central Indian sample, with oval being the most prevalent shape. The findings reinforce the importance of recognizing STF variants in surgical and radiological contexts and highlight the inverse relationship between septal thickness and foramen formation. These results contribute valuable regional data for anatomical and clinical reference.

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Introduction

The supratrochlear foramen (STF) of the humerus is an anatomical variation observed in the distal part of the humerus, where a thin bony septum between the olecranon and coronoid fossae becomes perforated. This foramen is more commonly found in dry bones than in radiological studies, and its incidence varies significantly across different populations and ethnic groups. The STF has been reported in approximately 6.9% to 60% of humeri worldwide [1], with higher prevalence noted in Indian populations compared to Caucasian or African populations. In Indian studies, its incidence has ranged between 27% and 34% [2,3], suggesting a distinct racial or genetic predisposition.

Morphologically, the STF can be round, oval, or irregular in shape, with oval being the most common. It is more frequently found on the left side and is slightly more common in males than females [4]. The presence of STF has important clinical implications. Radiologically, it may appear as a cystic or lytic lesion, leading to diagnostic confusion. Orthopedically, its presence can affect surgical approaches for procedures involving the distal humerus, such as retrograde intramedullary nailing or fracture fixation. The foramen may act as a weak spot, predisposing the bone to pathological or iatrogenic fractures [5].

Embryologically, the STF results from incomplete ossification of the septum between the coronoid and olecranon fossae. It is considered a phylogenetic remnant, commonly found in some primates and animals such as dogs and cats [6]. From an anthropological viewpoint, the STF is considered a non-metric trait used in the study of population dynamics, human evolution, and forensic identification [7].

Despite these implications, limited morphometric data are available from North Indian populations. Most existing studies are restricted to qualitative descriptions or isolated geographic regions [3,5]. Hence, a detailed morphometric analysis focusing on the dimensions, shape, laterality, and incidence of STF in this region is essential. This study aimed to bridge that gap by providing comprehensive morphometric data on STF using dry humeri of known Indian origin, thereby contributing valuable insights to anatomy, orthopedics, radiology, and forensic sciences.

Material and methods

Study Design and Duration

This was a descriptive cross-sectional study conducted in the Department of Anatomy at medical college in North India. The study was carried out over a period of one year, from January 2024 to December 2024, with the aim of evaluating the incidence, shape, size, and laterality of

the supratrochlear foramen (STF) in dry adult humeri of Indian origin.

Sample Size and Selection Criteria

A total of 127 dry adult human humeri were included in the study. These bones were obtained from the departmental osteology museum collection. All humeri were fully ossified, without any gross deformities or pathological lesions, and were of known Indian origin. Bones with fractured or damaged distal ends, malformed fossae, or post-mortem artifacts were excluded. The side (right or left) of each humerus was determined based on standard anatomical features such as the orientation of the humeral head, deltoid tuberosity, and the articular surface of the trochlea and capitulum.

Morphological and Morphometric Assessment

Each humerus was macroscopically examined for the presence or absence of a supratrochlear foramen. In bones where the foramen was present, its shape was noted and classified as oval, round, or irregular based on direct visual observation. Morphometric measurements of the STF were performed using a digital Vernier caliper with 0.01 mm precision. The vertical (superoinferior) and transverse (mediolateral) diameters of the foramen were measured to assess its size. In bones without a foramen, the thickness of the supratrochlear septum was measured using a thin stainless-steel probe and a millimeter scale, by gently inserting the probe through the olecranon and coronoid fossae.

Side-Wise Distribution

To assess any laterality in the occurrence of STF, the humeri were categorized into right and left-sided bones. The incidence, shape, and morphometric dimensions of the foramen were documented separately for each side. The frequency distribution was used to identify any side dominance in the occurrence of STF.

Statistical Analysis

All collected data were entered into Microsoft Excel 2019 and analyzed using IBM SPSS version 20.0. Descriptive statistics such as mean, standard deviation, and percentages were calculated for all parameters. The Chi-square test was used to determine statistical significance in the incidence of STF between right and left sides. Independent sample t-tests were applied to compare the mean diameters of STF between sides. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

Although the study involved only dry human bones from an existing academic collection, prior approval was obtained from the Institutional Ethics Committee. All

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protocols were followed in accordance with the ethical standards of human anatomical research.

Results

Out of the 127 humeri examined, 64 (50.4%) were from the right side and 63 (49.6%) from the left. The supratrochlear foramen (STF) was observed in 39 humeri (30.7%), with a slightly higher frequency on the left side (33.3%) compared to the right (28.1%). Among the remaining bones without STF, an opaque septum was

noted in 65 humeri (51.2%), more commonly on the left (52.4%) than the right (50.0%). A translucent septum was present in 23 humeri (18.1%), seen more frequently on the right side (21.9%) compared to the left (14.3%). These findings indicate a relatively symmetrical distribution of STF and septal variations between sides, with a marginal predominance of STF on the left (Table 1).

Table 1: Distribution of Supratrochlear Foramen and Septal Variants According to Side (n = 127).

Table 1: This study

Side	Total humeri	Supratrochlear	Opaque	Translucent
	Frequency (%)			
Right Side	64 (50.4%)	18 (28.1%)	32 (50.0%)	14 (21.9%)
Left Side	63 (49.6%)	21 (33.3%)	33 (52.4%)	9 (14.3%)
Total	127 (100%)	39 (30.7%)	65 (51.2%)	23 (18.1%)

Among the 39 humeri exhibiting a supratrochlear foramen, the oval shape was the most frequently observed morphology, seen in 16 bones (41.0%), followed by the round shape in 10 cases (25.6%). The reniform shape was noted in 5 humeri (12.8%), while seive-like and triangular shapes were observed in 3 cases each (7.7%). The rectangular type was the least common, present in only 2 humeri (5.1%). Side-wise comparison showed that oval and round shapes were predominant on both sides, with oval being more frequent on the left (42.9%) and round on the right (33.3%). However, the distribution of STF shapes between the right and left sides did not show a statistically significant difference ($p = 0.788$). These findings are consistent with previous Indian studies, which also report oval as the most prevalent STF shape (Table 2).

Table 2: Morphological Shapes of Supratrochlear Foramen on Right and Left Sides (n = 39).

Shape	Right Side (n = 18)	Left Side (n = 21)	Total (n = 39)	P value
	Frequency (%)			
Round	6 (33.3%)	4 (19.0%)	10 (25.6%)	0.788
Oval	7 (38.9%)	9 (42.9%)	16 (41.0%)	
Reniform	2 (11.1%)	3 (14.3%)	5 (12.8%)	
Seive	1 (5.6%)	2 (9.5%)	3 (7.7%)	
Triangular	1 (5.6%)	2 (9.5%)	3 (7.7%)	
Rectangular	1 (5.6%)	1 (4.8%)	2 (5.1%)	

The morphometric analysis of supratrochlear foramen in 39 humeri (18 right, 21 left) revealed no statistically significant side-wise differences in measured parameters. The mean distance from the medial epicondyle to the foramen was 24.8 ± 1.6 mm on the right and 25.1 ± 1.3 mm on the left ($p = 0.617$). The distance from the lateral epicondyle was 28.5 ± 1.8 mm on the right and 28.1 ± 1.5 mm on the left ($p = 0.479$). The vertical distance from the lower trochlear margin measured 4.6 ± 0.8 mm on the right and 4.4 ± 0.9 mm on the left ($p = 0.631$). Regarding foramen dimensions, the transverse diameter was slightly larger on the left (6.2 ± 0.9 mm) than the right (5.9 ± 0.8 mm), while the vertical diameter was 3.9 ± 0.7 mm on the left and 3.7 ± 0.6 mm on the right; however, these differences were also not statistically significant ($p = 0.299$ and 0.415 , respectively). These measurements suggest bilateral symmetry in the morphometric characteristics of the supratrochlear foramen (Table 3).

Table 3: Morphometric Parameters of Supratrochlear Foramen in Right and Left Humeri.

Parameters	Right Side	Left Side	P value
	Mean \pm SD (mm)		
Point Measurements			
Distance from Medial Epicondyle	24.8 ± 1.6	25.1 ± 1.3	0.617
Distance from Lateral Epicondyle	28.5 ± 1.8	28.1 ± 1.5	0.479

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Distance from Lower Trochlear Margin	4.6 ± 0.8	4.4 ± 0.9	0.631
Diameter of Foramen			
Transverse Diameter	5.9 ± 0.8	6.2 ± 0.9	0.299
Vertical Diameter	3.7 ± 0.6	3.9 ± 0.7	0.415

Among the 88 humeri without a supratrochlear foramen, the mean septal thickness was 5.2 ± 0.9 mm on the right side ($n = 46$) and 5.0 ± 1.0 mm on the left side ($n = 42$), with an overall mean of 5.1 ± 0.9 mm. The septal thickness ranged from 3.5 to 7.0 mm on the right and from 3.2 to 6.8 mm on the left, with a combined range of 3.2 to 7.0 mm. Although the right side showed marginally greater thickness, the difference was not statistically significant. These findings suggest that a thicker septum is associated with the absence of a supratrochlear foramen, aligning with prior studies from the Indian population (Table 4).

Table 4: Supratrochlear Septal Thickness in Bones Without Foramen (Mean ± SD in mm).

Side	Total humeri	Septal Thickness	Range (mm)
Right side	46	5.2 ± 0.9	3.5–7.0
Left side	42	5.0 ± 1.0	3.2–6.8
Total	88	5.1 ± 0.9	3.2–7.0

Discussion

The supratrochlear foramen (STF) of the humerus is a morphologically significant anatomical variation frequently studied due to its clinical, anthropological, and evolutionary implications. In the present osteological study of 127 dried adult humeri of unknown sex and age from the central Indian population, the STF was observed in 30.7% of the specimens, with a marginal predominance on the left side (33.3%) compared to the right (28.1%). This finding is consistent with earlier Indian studies such as those by Dang et al., and Nayak et al., who reported STF incidences of 30% and 34.4% respectively [8,9]. The incidence varies widely Joshi et al., documented 35.5% in Western Indians, while Krishnamurthy et al., found an incidence of 23% in South India [10,11]. Ndou reported a significantly common prevalence of 32.5% in South African populations, and but in contrast Papaloucas et al., observed only 0.3% in Greek [12,13]. These wide differences underscore the influence of ethnic, genetic, and geographical factors on STF occurrence [14].

The opaque septum was found in 51.2% and a translucent septum in 18.1% of humeri without STF. A translucent septum represents a thin bony partition that may be radiolucent on imaging and is often considered a precursor to STF formation. The presence of a translucent septum more frequently on the right side (21.9%) than the left (14.3%) may suggest differential biomechanical stress on the dominant upper limb, potentially leading to resorptive changes. Satish et al., and Ndou et al., have previously proposed that repeated elbow extension and triceps pressure can cause central thinning or perforation of the septum over time [15,16]. The lack of significant side-wise asymmetry in STF

occurrence, however, supports a developmental origin rather than a purely functional one [17].

Regarding shape analysis, the oval type STF was the most prevalent in our study (41.0%), followed by round (25.6%), reniform (12.8%), and less common types like triangular, seive-like, and rectangular shapes. These findings are comparable to Agrawal et al., who reported oval STFs in 61.3% of specimens, and Mathew et al., who found oval and round shapes in 51.6% and 21.6% respectively [18,19]. Variations in shape may result from non-uniform resorption of the septal bone or reflect differences in ossification centers during development. While reviews by Kunc et al., and Kunc et al., have proposed correlations between STF shape and foramen size, our results do not show significant shape distribution differences between sides ($p = 0.788$), indicating that shape is likely independent of limb dominance [20,21].

Morphometric evaluation of STF in 39 humeri (18 right and 21 left) revealed a mean distance from the medial epicondyle of 24.8 ± 1.6 mm on the right and 25.1 ± 1.3 mm on the left. The distance from the lateral epicondyle averaged 28.5 ± 1.8 mm (right) and 28.1 ± 1.5 mm (left), with no significant difference ($p > 0.05$). Similar results were reported by Laishram et al., and Mallikarjun et al., who found these distances ranged between 24–29 mm in Indian populations [22,23]. The mean vertical distance from the lower trochlear margin, approximately 4.5 mm, reflects the foramen's anatomical location within the thin central portion of the olecranon fossa. This is consistent with the hypothesis that STF forms in areas of least resistance and maximal stress transmission, especially during extension movements.

With respect to dimensions, the transverse diameter of STF was slightly higher on the left side (6.2 ± 0.9 mm)

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than the right (5.9 ± 0.8 mm), while vertical diameters measured 3.9 ± 0.7 mm and 3.7 ± 0.6 mm respectively [4]. These measurements reaffirm the predominance of an oval shape, and they are well-aligned with findings by Naqshi et al., and Coşkun et al., who documented average transverse diameters of 5.5–6.5 mm in Indian specimens [24,25]. No significant side-wise differences were observed in any of the morphometric parameters, suggesting bilateral anatomical symmetry of STF when present.

In the subgroup of 88 humeri without STF, the mean septal thickness was found to be 5.2 ± 0.9 mm on the right and 5.0 ± 1.0 mm on the left, with a total mean of 5.1 ± 0.9 mm. These values are in line with Chhabra et al., who reported septal thicknesses ranging between 4.5 to 6.8 mm in humeri without foramen [26]. It is widely accepted that a thicker septum (>4.5 mm) reduces the likelihood of resorption and perforation, hence STF formation. Thinner septa (<3.5 mm) are more prone to mechanical erosion. This supports the theory that STF formation is influenced by both congenital septal thinness and acquired stress-induced resorption [26].

From a clinical standpoint, the presence of STF holds significance for orthopedic surgeons and radiologists. It may be misinterpreted as a pathological radiolucency such as an osteolytic lesion on imaging, leading to unnecessary investigations [3]. Additionally, during intramedullary fixation, the presence of STF may compromise the integrity of the distal humerus, as the foramen represents a zone of structural weakness [4]. Knowledge of STF morphology can help modify surgical approaches and prevent iatrogenic fractures or implant misalignment. Furthermore, its identification is useful in anthropological studies for estimating humeral bone types, evolutionary adaptations, or even side determination in fragmented skeletal remains [8]

Conclusion

In conclusion, this study reinforces the importance of STF as a frequently encountered anatomical variation in the Indian population. Its incidence, shape variability, morphometry, and septal thickness findings are in agreement with several Indian studies, while also contributing new region-specific data. The symmetrical nature of STF and its developmental underpinnings are supported by the absence of statistically significant side differences across parameters. This underscores the value of documenting population-based anatomical norms, particularly in regions like North India, where such data remain sparse.

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