

Morphometric Study of the Supratrochlear Foramen of Humerus: A Cross-sectional Study from Gujarat, India

ADITYA A MUSALE¹, KINJAL JETHVA², HETAL VAISHNANI³, BHOOPESH RAJA⁴, JAHNAVI NATH⁵

ABSTRACT

Introduction: The Supratrochlear Foramen (STF) is a developmental perforation of the thin bony septum separating the coronoid and olecranon fossae of the distal humerus. Its prevalence varies widely between populations and it is clinically relevant because it may narrow the medullary canal, mimic a lytic lesion on radiographs, and act as a population-specific anthropological marker.

Aim: To determine the incidence and morphometric characteristics of the STF in dry adult human humeri from a Gujarati cadaveric collection.

Materials and Methods: A cross-sectional study was conducted on dry adult human humeri from a Gujarati cadaveric collection in the Department of Anatomy, SBKS Medical Institute and Research Centre, Vadodara, over six months (May-October 2025), after ethics approval from the Sumandeep Vidyapeeth Institutional Ethics Committee (SVIEC). Fifty-five dry adult humeri with intact epicondyles were examined. Transverse Diameters (TD) and Vertical Diameters (VD) of STF were measured with vernier calipers, Epicondylar Breadth (EB) on an osteometric board, and distances from

Medial Epicondyle (ME) and Lateral Epicondyles (LE) to STF borders (MB, LB) with sliding calipers; each measurement was averaged from three readings. Data were analysed using descriptive statistics, paired t-tests and Pearson correlation, with $p < 0.05$ considered significant.

Results: STF was identified in 13 of 55 humeri (23.64%), with a slight right-side predominance (7/13, 53.85%). Oval was the commonest shape (6/13, 46.15%), followed by round (5/13, 38.46%), triangular (1/13, 7.69%) and irregular (1/13, 7.69%). Mean TD (5.00 ± 3.19 mm) was significantly greater than mean VD (3.80 ± 2.11 mm; $t = 2.747$, $p = 0.018$), confirming an elliptical configuration. Mean LB (26.21 ± 3.58 mm) significantly exceeded mean MB (24.32 ± 3.30 mm; $t = -2.435$, $p = 0.031$), indicating that the foramen lies closer to the ME. Mean EB was 55.54 ± 6.65 mm.

Conclusion: STF is a frequent variant with predominantly oval morphology and medial displacement. Awareness of these values is important for preventing complications during intramedullary nailing, avoiding radiological misinterpretation, and supporting population-specific anthropological data.

Keywords: Cadaveric study, Distal humerus, Elbow joint, Olecranon fossa, Septal aperture

INTRODUCTION

The distal end of the humerus is a complex anatomical structure that participates in the elbow joint and houses two prominent fossae: the coronoid fossa anteriorly and the olecranon fossa posteriorly. These fossae are separated by a thin bony septum that contributes to the biomechanics of elbow flexion and extension [1]. In a proportion of individuals, this septum undergoes perforation during development, resulting in an anatomical variant known as the STF, also referred to in the literature as the septal aperture, olecranon-coronoid foramen or supratrochlear aperture [1,2].

The reported incidence of the STF varies widely across populations: it is generally low in European samples but considerably higher in Asian and African populations [3-5], making it a useful marker in studies of population variation and human skeletal biology.

From an orthopaedic perspective, the Supratrochlear Foramen (STF) is associated with a narrower distal humeral medullary canal, which may complicate retrograde intramedullary nailing and, to a lesser extent, antegrade nailing, while also influencing fracture propagation at the supracondylar level [2,4].

Given the wide variation in incidence and morphology across populations, robust population-specific data are needed before the STF can be reliably applied as an anthropological marker. Indian and South Asian data on the STF have been reported by Nayak SR et al., Mathew AJ et al., and Chhabra PK et al., but published data from the Gujarat region remain limited [4,6,7].

Against this background, the present study was undertaken to determine the incidence and morphometric characteristics of the STF in dry adult human humeri available in the Department of Anatomy at SBKS Medical Institute and Research Centre, Vadodara.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Anatomy at SBKS Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India over a six-month period (May 2025 to October 2025). The protocol was approved by the SVIEC (IEC approval no.: SVIEC/ON/MEDI/SRP/JAN/26/74); before commencement of data collection. As the study used previously catalogued dry bone specimens with no patient-identifiable data, individual informed consent was not applicable; the work was conducted in accordance with the principles of the Declaration of Helsinki [8].

Sample: A convenience sample comprising all 55 dry adult human humeri available in the departmental osteology collection that satisfied the eligibility criteria was examined. Sex and age data were not consistently documented for the specimens and were therefore not analysed.

Inclusion criteria:

1. Dry adult human humeri with intact epicondyles;
2. Specimens in which the STF, when present, was clearly identifiable in its entirety;

- Specimens with both ME and LE preserved to allow accurate EB measurement.

Exclusion criteria:

- Humeri with significant deformities, fractures, erosion or surgical alteration of the distal end;
- Specimens with damage compromising the integrity of either epicondyle or the septum between coronoid and olecranon fossae;
- Paediatric or incompletely ossified humeri.

Identification of side and shape

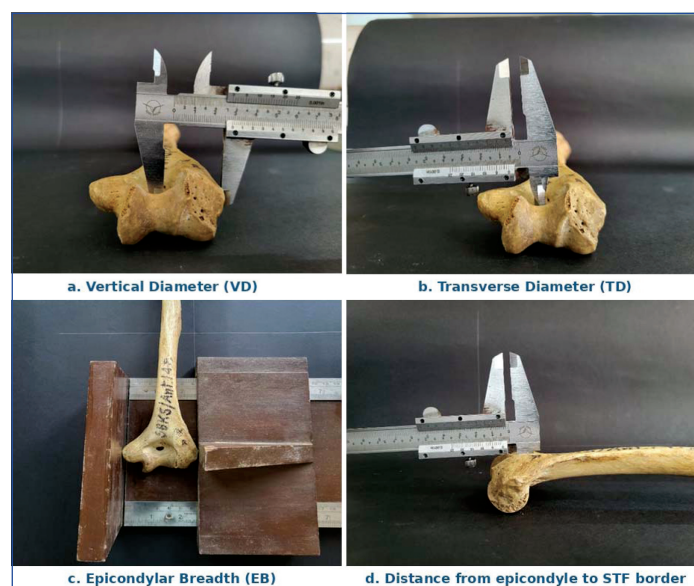
The side (right or left) of each humerus was identified using standard anatomical landmarks. When STF was present, its shape was visually classified into one of four categories- oval, round, triangular or irregular (sieve-like)- based on the morphology of the perforation as observed against transmitted light, following the four-category shape classification (oval, round, triangular and irregular/sieve-like) described by Nayak SR et al., [7].

Morphometric measurements

Five morphometric parameters were recorded for every specimen in which STF was identified:

- Transverse Diameter (TD): maximum horizontal width of the foramen, measured with extended-jaw vernier calipers.
- Vertical Diameter (VD): maximum vertical height of the foramen, measured with extended-jaw vernier calipers.
- Epicondylar Breadth (EB): maximum distance between the most lateral points of the ME and LEs, measured on an osteometric board.
- ME-MB distance: distance from the most medial point of the ME to the medial border of the STF (MB), measured with sliding calipers.
- LE-LB distance: distance from the most lateral point of the LE to the lateral border of the STF (LB), measured with sliding calipers.

All measurements were taken with vernier calipers of 0.01 mm least count and recorded in millimetres. To minimise observer bias, every parameter was measured three times by a single observer, and the arithmetic mean of the three readings was used for analysis. The methodological set-up is illustrated in [Table/Fig-1].



[Table/Fig-1]: Methodological photographs showing morphometric measurements of the Supratrochlear Foramen (STF): a) Vertical Diameter (VD) measured with extended-jaw vernier calipers; b) Transverse Diameter (TD) measured horizontally; c) Epicondylar Breadth (EB) measured on an osteometric board; d) Distance from epicondyle to STF border measured with sliding calipers.

STATISTICAL ANALYSIS

Data were entered into Microsoft Excel and analysed using Python 3.11 with SciPy 1.11 [9]. Continuous variables were reported as Mean±Standard Deviation (SD), Median and Range. Categorical variables were reported as frequencies and percentages. In addition to TD and VD, the ME-MB distance, the LE-LB distance, the Epicondylar Breadth were also tested with the Shapiro-Wilk test and did not deviate significantly from normality, justifying the paired Student t-test for the ME-MB versus LE-LB comparison and the unpaired Student t-test for the right-versus-left comparison of EB. The strength of linear association between continuous parameters was assessed using Pearson's correlation coefficient (r). A two-tailed p-value of less than 0.05 was considered statistically significant. All 13 humeri exhibiting an STF provided complete measurements for all five morphometric parameters; there were no missing values.

RESULTS

Of the 55 dry adult human humeri examined, the STF was identified in 13 specimens, giving an overall incidence of 23.64% [Table/Fig-2]. Among the 13 humeri with STF, 7 (53.85%) were right-sided and 6 (46.15%) were left-sided, indicating a slight right-side predominance [Table/Fig-3] shows representative dry humeri from the studied collection in which the STF was clearly visible at the distal end.

Parameter	Number	Percentage (%)
Total humeri examined	55	100.00
Humeri with STF	13	23.64
Humeri without STF	42	76.36

[Table/Fig-2]: Incidence of Supratrochlear Foramen (STF) (n=55).
STF: Supratrochlear foramen



(a) Left-side humeri with STF (n = 6)



(b) Right-side humeri with STF (n = 7)

[Table/Fig-3]: Side distribution of humeri with Supratrochlear Foramen (STF): a) The six left-side humeri (n=6, 46.15%); b) The seven right-side humeri (n=7, 53.85%) demonstrating the slight right-side predominance.

Shape distribution

On visual classification, four distinct morphological types of STF were observed [Table/Fig-4]. The oval (elliptical) shape was the most common, present in six of 13 STF (46.15%), followed by the

round shape in 5 (38.46%), the triangular shape in 1 (7.69%) and the irregular or sieve-like shape in 1 (7.69%) [Table/Fig-5].



[Table/Fig-4]: Morphological types of the Supratrochlear Foramen (STF) observed in the present study: (a) round; (b) oval; (c) triangular; (d) irregular (sieve-like).

Shape	Number	Percentage (%)
Oval	6	46.15
Round	5	38.46
Triangular	1	7.69
Irregular (sieve-like)	1	7.69
Total	13	100.00

[Table/Fig-5]: Shape distribution of Supratrochlear Foramen (STF) (n=13).

Note: Percentages are rounded to two decimal places and may therefore sum to 99.99% rather than exactly 100% (46.15 + 38.46 + 7.69 + 7.69=99.99).

Morphometric measurements

The mean TD of the STF was 5.00 ± 3.19 mm (range 1.20–11.70 mm) and the mean VD was 3.80 ± 2.11 mm (range 1.20–7.80 mm) [Table/Fig-6].

Parameter	Mean $\pm$ SD (mm)	Median (mm)	Range (mm)
Vertical Diameter (VD)	3.80 ± 2.11	3.20	1.20 - 7.80
Transverse Diameter (TD)	5.00 ± 3.19	3.90	1.20 - 11.70
Epicondylar Breadth (EB)	55.54 ± 6.65	58.00	46.00–65.00
ME to medial border of STF (MB)	24.32 ± 3.30	23.80	19.80–29.60
LE to lateral border of STF (LB)	26.21 ± 3.58	26.10	21.20–34.10

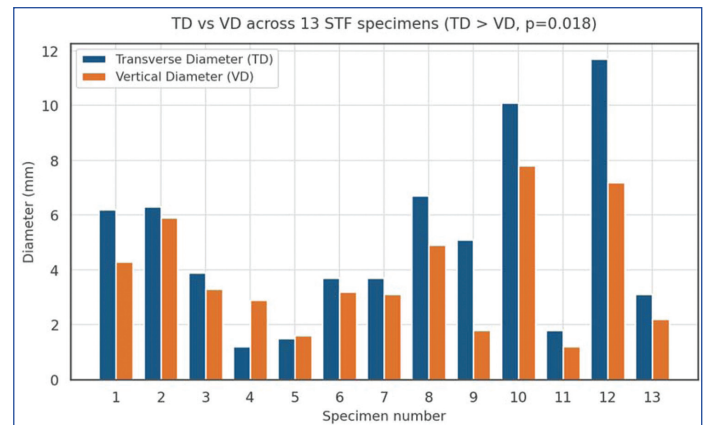
[Table/Fig-6]: Morphometric measurements of the Supratrochlear Foramen (STF) (n=13).

SD: Standard deviation; ME: Medial epicondyle; LE: Lateral epicondyle; MB: Medial border of STF; LB: Lateral border of STF

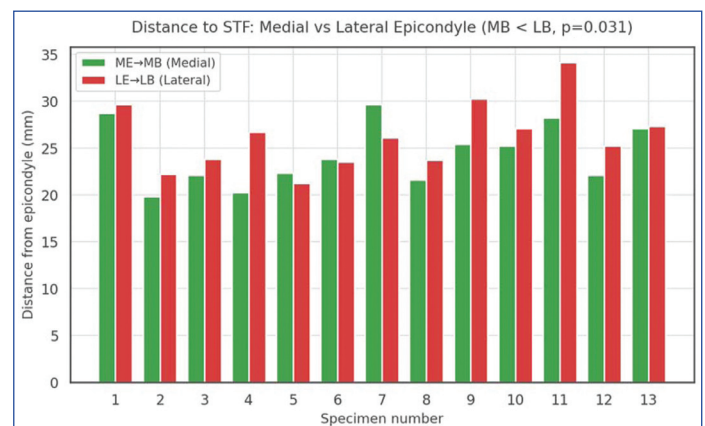
Statistical comparisons

Transverse and VDs were compared in order to test objectively whether the foramen is elliptical rather than circular; this distinction is anatomically and clinically relevant, because a transversely elongated aperture implies that the narrowest cross-section of the residual supratrochlear bony bridge- the corridor most relevant to retrograde intramedullary nailing- is oriented transversely. Shapiro-Wilk testing showed that the distributions of TD ($W=0.914$, $p=0.211$) and VD ($W=0.919$, $p=0.245$) did not deviate significantly from normality, justifying the use of parametric tests. A paired t-test demonstrated that TD was significantly greater than VD across the 13 specimens (mean difference 1.20 mm; $t=2.747$, $p=0.018$; Cohen's $d=0.762$), confirming an elliptical configuration of the foramen with the long axis oriented transversely [Table/Fig-7].

Similarly, the LE-LB distance was significantly greater than the ME-MB distance (mean difference 1.89 mm; paired $t=-2.435$, $p=0.031$; Cohen's $d=0.675$), indicating that the foramen is consistently positioned closer to the ME than to the LE [Table/Fig-8]. Pearson correlation analysis showed a very strong positive correlation between TD and VD ($r=0.902$; $p<0.001$; 95% CI 0.70–0.97), indicating proportional scaling of the two diameters, and strong positive correlations of EB with both ME-MB ($r=0.798$; $p=0.001$; 95% CI 0.44–0.94) and LE-LB ($r=0.825$; $p<0.001$; 95% CI 0.50–0.95), suggesting that larger humeri tend to have proportionately greater distances between the foramen and both epicondyles.



[Table/Fig-7]: Specimen-level comparison of Transverse Diameter (TD) and Vertical Diameter (VD) across the 13 humeri with Supratrochlear Foramen (STF). TD exceeded VD in the majority of specimens (paired $t=2.747$, $p=0.018$).



[Table/Fig-8]: Specimen-level comparison of distance from Medial Epicondyle (ME) to medial border of STF (ME-MB) and from lateral epicondyle to lateral border of STF (LE-LB). LE-LB was greater than ME-MB in the majority of specimens (paired $t=2.435$, $p=0.031$), confirming the medial position of the foramen.

Of the five parameters, only EB differed significantly between the two sides ($p=0.027$), being greater on the right; the remaining parameters showed no statistically significant side-to-side difference [Table/Fig-9].

Parameter	Right-side (n=7)	Left-side (n=6)	p-value
Transverse Diameter (TD) (mm)	6.03 ± 3.70	3.80 ± 2.19	0.223
Vertical Diameter (VD) (mm)	4.03 ± 2.65	3.53 ± 1.45	0.692
Epicondylar Breadth, (EB) (mm)	59.14 ± 4.38	51.33 ± 6.62	0.027
ME to medial border, ME-MB (mm)	25.60 ± 2.98	22.82 ± 3.23	0.135
LE to lateral border, LE-LB (mm)	27.67 ± 3.48	24.50 ± 3.12	0.114

[Table/Fig-9]: Side-wise (right vs left) comparison of morphometric parameters of the Supratrochlear Foramen (STF).

Values are expressed as Mean $\pm$ SD; Right-versus-left comparisons were performed using the unpaired Student t-test, with $p<0.05$ considered statistically significant. ME: Medial epicondyle; LE: Lateral epicondyle; MB: Medial border of STF; LB: Lateral border of STF

DISCUSSION

In the present series of 55 dry adult human humeri from a Gujarati cadaveric collection, the STF was identified in 13 specimens, giving an incidence of 23.64%.

Nayak SR et al., and Mathew AJ et al., reported incidence rates in the moderate-to-high range in South Indian samples [6,7], and Chhabra PK et al., observed STF in 12 of 71 humeri (16.9%) in a North Indian sample using both gross and computed tomography assessments [4].

Morphologically, the oval shape was the most prevalent in our sample (46.15%), followed by round, triangular and irregular sieve-like forms. This ordering is concordant with previous reports by Nayak SR et al., Erdogan S et al., and Coşkun ZK et al., all of whom found oval STF to be the predominant morphology

across diverse populations [3,7,10]. The mean transverse (5.00 mm) and vertical (3.80 mm) diameters recorded here are broadly comparable to those reported by Erdogmus S et al., (TD 5.93 mm, VD 4.06 mm) [3] and Li J et al., [5] (left-side TD 4.47 mm, VD 5.07 mm), but smaller than the values reported by Chhabra PK et al., for oval and reniform foramina (mean TD 8.17 mm, VD 5.27 mm) [4]; these differences most plausibly reflect genuine inter-population variation together with methodological factors such as the range of shapes pooled into the averaged measurement, the type of calliper used and whether translucent (incompletely perforated) septa were counted as foramina [Table/Fig-10] [1,3-5,11].

Study (year)	Population	Humeri examined	STF incidence
Ndou R et al., (2013) [1]	South Africa	-	≈33% (about one-third)
Erdogmus S et al., (2014) [3]	Turkey	166	10.8%
Li J et al., (2015) [5]	China (Jining)	262	10.3%
Chhabra PK et al., (2023) [4]	North India	71	16.9%
Boonchan S et al., (2022) [11]	Thailand	640	16.1%
Present study (2025)	West India (Gujarat)	55	23.64%

[Table/Fig-10]: Incidence of the Supratrochlear Foramen (STF) reported across representative published series [1,3-5,11].
STF: supratrochlear foramen. Incidence values are those reported in the cited studies; for Ndou R et al., the figure is an approximate value (about one-third) as stated in that report, and the exact denominator was not specified here

From a clinical perspective, the morphometric data have direct relevance for orthopaedic surgery. The presence of STF is consistently associated with a narrowed distal medullary canal [2,4], and the predominantly oval and medially-displaced foramen observed in our series may further restrict the safe corridor for retrograde intramedullary nailing of the humerus. The mean TD of approximately 5 mm- but with values up to 11.7 mm in our series- implies that the canal cross-section in the supratrochlear region can be substantially smaller than would be expected from radiographs of the proximal shaft, increasing the risk of cortical penetration, fracture propagation or nail mismatch; although large surgical series directly quantifying these complications are still lacking, a case of low-energy bilateral distal-humeral fracture attributed to a septal aperture has been documented [12], which lends limited empirical support to this concern. Pre-operative planning that includes orthogonal imaging of the distal humerus and recognition of the STF, when present, should therefore be considered before any procedure involving the supracondylar region.

Limitation(s)

Several limitations should be acknowledged. First, the sample of 55 humeri yielded only 13 specimens with STF; while sufficient to demonstrate statistically significant paired contrasts, this number limits the generalisability of incidence and shape proportions and precludes meaningful subgroup comparisons by side or shape. Second, sex and age data for the dry humeri were not available, so sexual dimorphism and age-related variation in STF morphology could not be assessed. Third, all measurements were performed by a single observer, and although triplicate measurements were averaged, formal inter-observer reproducibility was not tested. Fourth, only morphometric and shape variables were studied; the diameter of the medullary canal at the level of the foramen was not directly measured, so the inferred narrowing of the canal is based on previously published evidence rather than on direct measurement in this series. Finally, this is a single-centre study from a Gujarati cadaveric collection and the findings should be confirmed in larger multi-centre series, ideally with paired radiological assessment, before extrapolation to the wider Indian population.

CONCLUSION(S)

The STF is a frequent and clinically relevant anatomical variant of the distal humerus in this Gujarati cadaveric series, characterised

by a predominantly oval, transversely elongated configuration and a position consistently closer to the ME.

Declaration on the Use of Artificial Intelligence: ChatGPT and Artificial Intelligence tools were used to reframe and adjust the language and grammar for this manuscript.

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PARTICULARS OF CONTRIBUTORS:

- 1. Third Year Postgraduate Resident, Department of Anatomy, S.B.K.S. Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India.
- 2. Professor, Department of Anatomy, S.B.K.S. Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India.
- 3. Professor and Head, Department of Anatomy, S.B.K.S. Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India.
- 4. Third Year Postgraduate Resident, Department of Anatomy, S.B.K.S. Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India.
- 5. Third Year Postgraduate Resident, Department of Anatomy, S.B.K.S. Medical Institute and Research Centre, Sumandeep Vidyapeeth (Deemed to be University), Piparia, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Aditya A. Musale,
Flat No. 303, Block-E, 3rd Floor, Prime Plaza, Amodar, Vadodara-390019,
Gujarat, India.
E-mail: adityamusale222@gmail.com

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