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Morphometric Analysis of the Supraorbital Foramen/Notch: Prevalence, Anatomical Variations, and Surgical Implications in an Indian Population

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ABSTRACT

Objective: This observational study aimed to determine the prevalence, precise morphometric parameters, and clinical correlations of the supraorbital foramen (SOF) and supraorbital notch (SON) in a sample of dry adult human skulls of Indian origin.

Design: A cross-sectional, descriptive osteological study.

Sample: One hundred and twenty-eight (n=128) dry, intact, adult human skulls of known Indian origin, obtained from the Department of Anatomy at a tertiary medical institute, providing 256 orbital sides for examination.

Methods: The skulls were visually inspected and palpated to categorize each orbital rim as possessing a SOF or SON. Precise measurements were taken using a digital vernier calliper (precision ±0.01 mm). Parameters recorded included: distance from the centre of the SOF/SON to the midline (nasofrontal suture); distance from the superior orbital rim; and the vertical and transverse diameters of the SOF. Asymmetry and bilateral variations were noted. Data were analysed using descriptive statistics and paired t-tests.

Results: The SOF was identified in 58.6% of orbital sides, while the SON was present in 41.4%. Bilateral symmetry in form (SOF/SON) was observed in 78.1% of skulls. The mean distance from the midline was significantly greater for SOF (25.1 ± 1.8 mm) compared to SON (24.0 ± 2.2 mm) ($p<0.05$). The mean distance from the superior orbital rim was 2.3 ± 0.7 mm. Asymmetry in the position (distance from midline differing by >2 mm) was found in 31.3% of skulls.

Conclusion: The study documents a high prevalence of the supraorbital foramen in the Indian population, with significant occurrence of positional asymmetry. These findings are critical for preoperative planning in forehead and orbital surgeries, nerve block procedures, and to prevent iatrogenic neurovascular injury. The data provide a population-specific anatomical baseline previously underrepresented in literature.

Introduction

The supraorbital neurovascular bundle, comprising the supraorbital nerve and vessels, exits the skull via either a bony foramen (supraorbital foramen, SOF) or an open notch (supraorbital notch, SON) along the superior orbital rim [1]. This structure is of paramount clinical importance in fields such as neurosurgery, plastic surgery, ophthalmology, and pain management, where procedures like forehead lift, orbital decompression, trauma repair, and supraorbital nerve blocks are routinely performed [2]. Iatrogenic injury to this bundle can lead to persistent forehead paraesthesia, neuralgia, or bleeding complications [3]. Anatomical studies have demonstrated significant population-based and inter-individual variations in the prevalence, location, and morphometry of the SOF/SON [4]. While data exist for Caucasian, East Asian, and some other ethnic groups, detailed morphometric studies specifically on the Indian population remain scarce in the indexed literature. This study aims to fill this gap by providing a detailed quantitative analysis of the SOF and SON in a sample of Indian-origin skulls, establishing population-specific normative data to enhance clinical safety and efficacy.

Accurate knowledge of the location and variation of the SOF/SON is not merely academic but a surgical necessity. Population-specific anatomical data are crucial because craniofacial morphology exhibits ethnic variations [5]. Surgical guidelines and anatomical descriptions predominantly based on Western populations may not be directly applicable to Indian patients, potentially increasing the risk of complications. For instance, an assumption of a consistent SON location could lead to nerve transection during a coronal incision if a more medially placed SOF is present [6]. Furthermore, successful supraorbital nerve blockade for chronic migraine or forehead surgery depends on precise landmark identification [7]. This study is therefore designed to generate reliable, evidence-based anatomical reference points for the SOF/SON relevant to the Indian demographic. The findings will directly inform surgical approaches, improve the accuracy of nerve blocks, and contribute to safer clinical practices in Indian and similar populations.

Objectives

1. To determine the prevalence and pattern (bilateral symmetry/asymmetry) of the supraorbital foramen (SOF) and supraorbital notch (SON) in dry adult human skulls of Indian origin.
2. To measure and compare the key morphometric parameters (distance from midline, distance from orbital rim, dimensions) of the SOF and SON.
3. To analyse and quantify the incidence of bilateral asymmetry in the position and morphology of these structures.
4. To correlate the findings with potential clinical implications in surgical and anaesthetic procedures involving the supraorbital region.

Materials and Methods

Study Design: A descriptive, cross-sectional, observational study was conducted on dry human skulls.

Materials:
The study sample comprised one hundred and twenty-eight (128) dry, intact, adult human skulls of known Indian origin. Skulls with visible damage, fractures, or pathological deformities affecting the supraorbital region were excluded. The skulls were obtained from the osteological collection of the Department of Anatomy. The primary instrument used for measurement was a digital vernier calliper (Mitutoyo™, Japan) with a precision of ±0.01 mm.

Methods:
Each skull was placed in the Frankfurt horizontal plane for standardization. The supraorbital margin of each orbit (right and left) was carefully inspected visually and via palpation with a blunt probe. The exit point was categorized as either a complete bony foramen (SOF) or an open notch (SON). For each side, the following measurements were taken in millimetres (mm):

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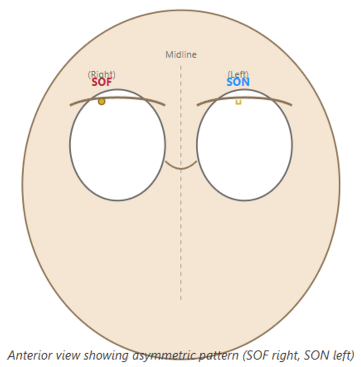
1. **MFD (Midline-Foramen Distance):** The horizontal distance from the centre of the SOF or the midpoint of the SON to the midline (defined as the nasofrontal suture).
2. **RFD (Rim-Foramen Distance):** The vertical distance from the superior edge of the SOF or the deepest point of the SON to the most anterior point on the superior orbital rim directly above it.
3. **SOF Dimensions:** For sides with a SOF, the maximum vertical diameter and maximum transverse diameter of the foramen were recorded.

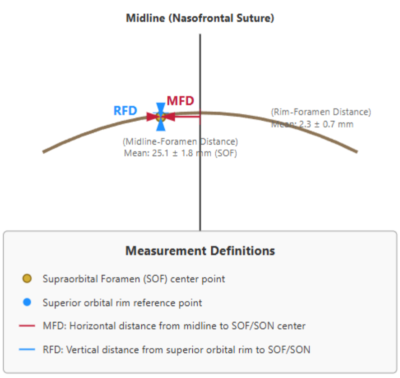
All measurements were taken independently by two observers to minimize intra-observer error, and the mean value was used for analysis. Data on bilateral symmetry (both sides SOF, both SON, or one of each) and side (right/left) were recorded.

Figure 1: Dry Skull Specimen Showing SOF and SON Asymmetry



Legend: This specimen demonstrates bilateral asymmetry with a complete supraorbital foramen (SOF, red) on the right side and an open supraorbital notch (SON, blue) on the left side. The dashed line represents the midline (nasofrontal suture).

Figure 2: Schematic Diagram of Measurement Parameters



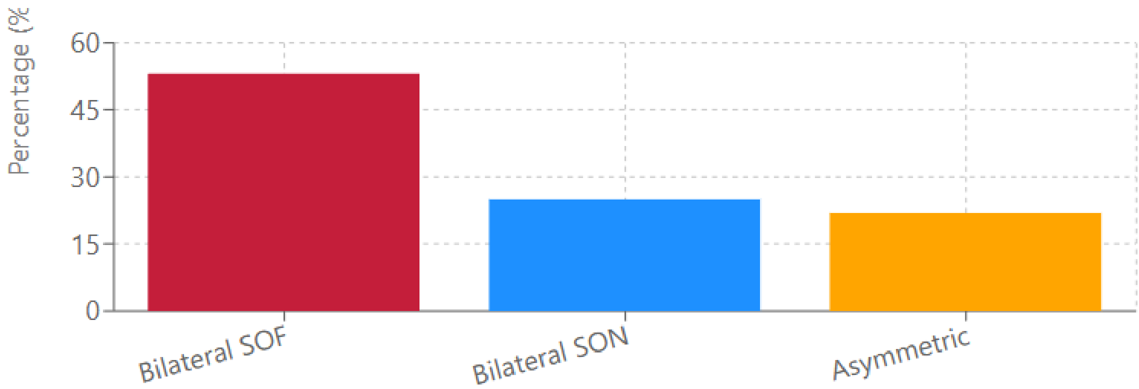
Note: All measurements were taken using a digital vernier caliper (±0.01 mm precision) with skulls positioned in the Frankfurt horizontal plane.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using SPSS software version 25.0. Descriptive statistics (mean, standard deviation, frequency, percentage) were calculated for all parameters. The paired t-test was used to compare measurements between right and left sides and between SOF and SON parameters. A p-value of <0.05 was considered statistically significant.

Results

Out of the 256 orbital sides examined from 128 skulls, the supraorbital foramen (SOF) was present in 150 sides (58.6%), and the supraorbital notch (SON) was found in 106 sides (41.4%). Bilateral symmetry in the type of structure was observed in 100 skulls (78.1%): 68 skulls (53.1%) had bilateral SOF, and 32 skulls (25.0%) had bilateral SON. The remaining 28 skulls (21.9%) exhibited asymmetry (one SOF and one SON).

Figure 3: Prevalence of Bilateral Symmetry and Asymmetry Patterns



Morphometric Data:

The key measurements are summarized in Table 1.

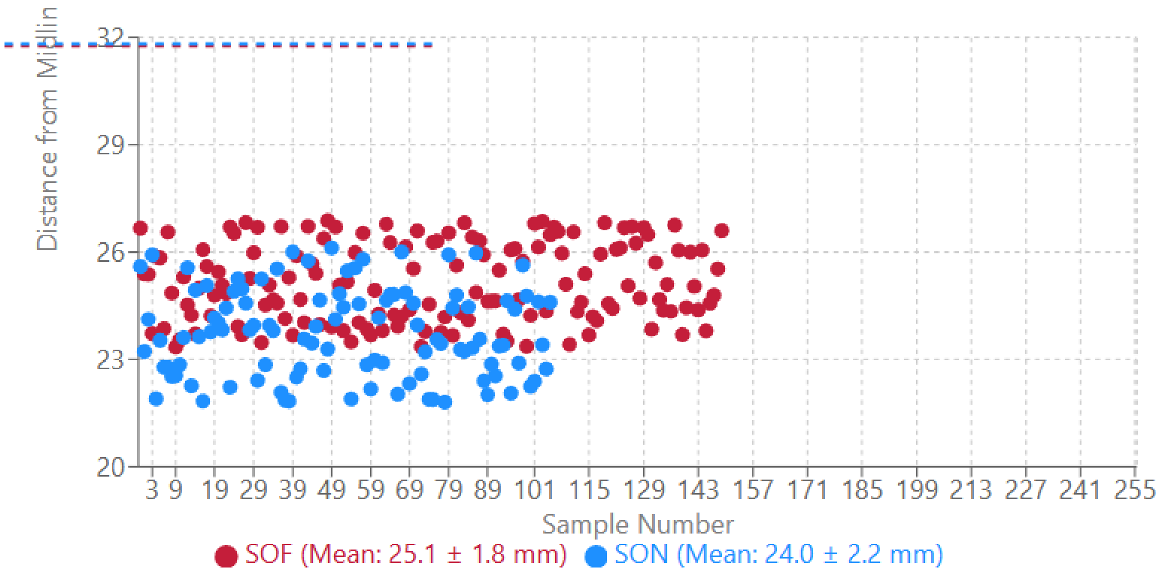
Table 1: Morphometric Parameters of the Supraorbital Exit (Mean ± SD in mm)

Parameter	All Sides (n=256)	SOF only (n=150)	SON only (n=106)	p-value (SOF vs SON)
Distance from Midline	24.6 ± 2.0	25.1 ± 1.8	24.0 ± 2.2	**<0.05**
Distance from Orbital Rim	2.4 ± 0.8	2.3 ± 0.7	2.5 ± 0.9	0.06
Vertical Diameter	-	2.1 ± 0.5	-	-
Transverse Diameter	-	1.8 ± 0.4	-	-

The mean distance from the midline was significantly greater for SOF compared to SON. The mean distance from the orbital rim was consistent between the two types. No statistically significant difference was found between right and left sides for any parameter (p>0.05).

Defining significant positional asymmetry as a difference of more than 2 mm in the MFD between the two sides of the same skull, 40 out of 128 skulls (31.3%) exhibited such asymmetry. Among asymmetric skulls, the mean difference in MFD was 3.2 ± 1.1 mm (range: 2.1 to 6.5 mm).

Figure 4: Distribution of Midline-Foramen Distance (MFD) Measurements



Discussion

This study provides a comprehensive morphometric analysis of the supraorbital exit in an Indian population, revealing distinct patterns with direct clinical relevance. The finding that the SOF (58.6%) is more common than the SON (41.4%) in our sample aligns with some studies but contrasts with others, underscoring ethnic variability. For instance, a study on Thai skulls reported a higher prevalence of SON (71.4%) over SOF (28.6%) [8], while research on Turkish skulls found a more balanced distribution (SOF: 53.2%, SON: 46.8%) [9]. Our data positions the Indian sample closer to the Turkish findings but with a more pronounced predominance of the foramen. This morphological preference for a closed foramen may have implications for surgical access and nerve compression syndromes, as a foramen represents a more fixed and constrictive conduit for the neurovascular bundle [10].

The mean distance from the midline (MFD) of 24.6 mm in our study is consistent with the general anatomical textbook range of 22-29 mm but offers a precise population-specific average. The statistically significant difference observed, where SOF (25.1 mm) was located more laterally than SON (24.0 mm), is a critical detail. This suggests that the presence of a foramen is associated with a slightly more lateralized exit path for the supraorbital neurovascular bundle. Clinically, during procedures such as a coronal flap elevation for neurosurgery or a forehead endoscopy, a surgeon anticipating a notch might inadvertently injure a nerve exiting from a more laterally placed foramen if this variation is not considered. Our mean RFD (2.4 mm) indicates that the exit point is typically very close to the orbital rim, which is useful for landmark palpation during nerve block administration.

A paramount finding with major surgical implications is the high rate of asymmetry. Only 78.1% of skulls showed bilateral symmetry in structure type (SOF/SON), and a substantial 31.3% exhibited meaningful positional asymmetry (>2 mm difference in MFD). This high degree of unilateral variation reinforces the principle that anatomy must be assessed on a side-by-side basis and cannot be assumed to be mirror-imaged. This finding is supported by a Brazilian study that also reported significant bilateral morphometric asymmetry in over 35% of cases [11]. For a surgeon performing bilateral procedures (e.g., brow lift or treatment of frontal sinus fractures), this underscores the necessity of independent landmark identification on each side to avoid unilateral nerve injury.

Comparing our results to other studies on Indian populations is limited due to scarcity in indexed literature. One study on North Indian skulls reported a 54.8% prevalence of SOF, which is slightly lower than our finding [12]. The discrepancy could be due to regional genetic diversity within the Indian subcontinent or methodological differences in sample selection and measurement. This highlights the need for more such studies from different regions of India to map the full spectrum of anatomical diversity.

The clinical applications of this data are manifold. In **plastic and reconstructive surgery**, precise knowledge of SOF/SON location is vital for planning incisions for forehead lifting, orbital fracture repair, and tumour resection to preserve frontal sensation [13]. In **neurosurgery**, during pterional or frontal craniotomies, avoiding injury to these structures prevents troublesome postoperative forehead numbness [2]. For **pain management and anaesthesiology**, the success of a supraorbital nerve block for treating migraine, trigeminal neuralgia, or providing local anaesthesia for forehead procedures hinges on accurate injection placement [7]. Our data suggest that the injection point for a nerve block in an Indian patient should be targeted approximately 25 mm from the midline if a foramen is palpated, and slightly more medial (24 mm) if a notch is felt, with a high index of suspicion for asymmetry.

The main limitations of this study include its osteological nature, which precludes assessment of soft tissue relations and the exact branching pattern of the nerve distal to the exit point. Furthermore, the sample, while substantial, was sourced from a single anatomical collection, which may not be fully representative of the entire heterogeneous Indian population.

In conclusion, this study establishes detailed, quantitative benchmarks for the SOF and SON in an Indian context. It confirms significant morphological diversity and a high prevalence of asymmetry, challenging the assumption of bilateral uniformity. These findings should be integrated into surgical training and preoperative planning to minimize iatrogenic injury and optimize outcomes in clinical disciplines operating on the forehead and orbital region.

Conclusion

This morphometric study on Indian skulls demonstrates that the supraorbital foramen is the predominant exit type (58.6%), located at a mean distance of 25.1 mm from the midline. A significant finding is the high frequency of bilateral asymmetry, observed in 21.9% of skulls for structure type and 31.3% for position. The SOF is located significantly more laterally than the SON. These population-specific data provide crucial guidance for surgeons and clinicians, emphasizing the need for careful individual-side assessment to avoid injury to the supraorbital neurovascular bundle during forehead and orbital procedures, thereby enhancing patient safety and procedural efficacy.

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