MORPHOMETRIC ANALYSIS OF THE INFRAORBITAL FORAMEN IN ADULT HUMAN DRY SKULLS: A CROSS-SECTIONAL STUDY WITH CLINICAL SIGNIFICANCE

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INTRODUCTION

The infraorbital foramen (IOF) is an important anatomical landmark located on the anterior surface of the maxilla, approximately 6–10 mm below the infraorbital margin. It represents the external opening of the infraorbital canal through which the infraorbital nerve, artery, and vein emerge onto the face(12). The infraorbital nerve is a continuation of the maxillary division of the trigeminal nerve and provides sensory innervation to the lower eyelid, side of the nose, upper lip, cheek, and adjacent facial skin. Due to its significant neurovascular contents and its relationship with surrounding facial structures, the infraorbital foramen holds considerable importance in clinical anatomy, dentistry, maxillofacial surgery, plastic surgery, and anesthesiology.

Precise localization of the infraorbital foramen is essential for performing effective infraorbital nerve block anesthesia, which is commonly employed during dental procedures, cleft lip repair, rhinoplasty, orbital surgeries, and treatment of maxillofacial trauma(1). Infraorbital nerve blocks are frequently preferred because they provide effective regional anesthesia with minimal tissue distortion and reduced systemic complications. However, failure to accurately identify the location of the infraorbital foramen may result in inadequate anesthesia, repeated needle insertion, patient discomfort, and injury to the infraorbital nerve or accompanying vessels(7).

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The infraorbital foramen also serves as a vital surgical landmark during open reduction and internal fixation of facial fractures, orbital floor reconstruction, endoscopic sinus surgery, cosmetic facial procedures, and maxillary osteotomies(2).

Surgeons operating in the midfacial region must possess detailed anatomical knowledge regarding the location, size, shape, and orientation of the infraorbital foramen to avoid accidental damage to the infraorbital neurovascular bundle. Injury to the infraorbital nerve may lead to postoperative complications such as numbness, paresthesia, chronic pain, or sensory deficits involving the upper lip, cheek, and nasal region(3).

Numerous studies have demonstrated that the infraorbital foramen exhibits considerable anatomical variations with respect to its shape, size, direction, number, and position relative to surrounding bony landmarks. The foramen may appear oval, round, triangular, irregular in shape, and accessory infraorbital foramina may occasionally be present(4). Variations have also been reported among different ethnic groups, sexes, and populations. Such differences may influence surgical approaches and anesthetic techniques. Therefore, population-specific morphometric data are important for clinicians to improve the safety and effectiveness of diagnostic and therapeutic procedures involving the infraorbital region(7).

Despite the increasing clinical relevance of the infraorbital foramen, limited morphometric studies have been conducted in the South Indian population(5). Detailed anatomical data regarding the dimensions and morphological variations of the infraorbital foramen can contribute significantly to anatomical knowledge and clinical practice. Hence, the present study was undertaken to evaluate the morphometric characteristics of the infraorbital foramen in adult human dry skulls and to analyze their clinical significance in relation to surgical and anesthetic procedures of the maxillofacial region.

Aim and Objectives

1. To determine the transverse and vertical diameters of the infraorbital foramen.
2. To measure its distance from important anatomical landmarks.
3. To analyze the shape and direction of the infraorbital canal.
4. To identify accessory infraorbital foramina.

MATERIALS AND METHODS

The present study was a descriptive cross-sectional observational study conducted in the Department of Anatomy at MVJ Medical College and Research Hospital, Hoskote, Bengaluru. The study was carried out on 130 adult dry human skulls obtained from the osteology collection of the department. The skulls used in the study were of unknown sex and age but were confirmed to be adult specimens based on the complete eruption of permanent dentition and fusion of cranial sutures.

Inclusion Criteria

- Intact adult dry human skulls with well-preserved maxillary regions
- Skull specimens with clearly identifiable infraorbital foramina on both sides

Exclusion Criteria

- Damaged or fractured skulls
- Skull specimens with deformities, pathological lesions, erosion, or congenital anomalies involving the maxillofacial region
- Skulls with obliterated or poorly defined infraorbital foramina

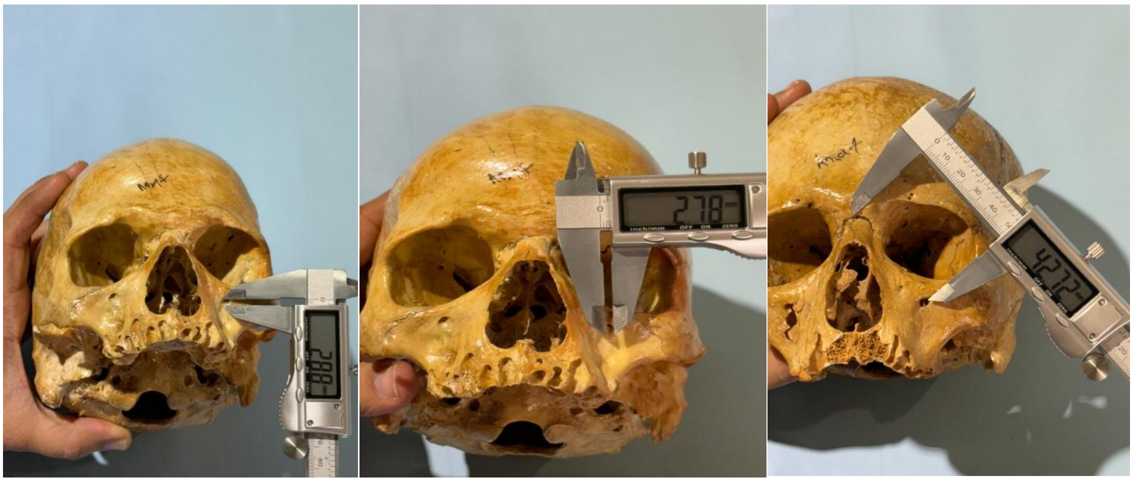
A total of 260 infraorbital foramina were examined bilaterally. Prior to measurement, each skull was carefully inspected for anatomical integrity. Morphometric measurements were obtained using a digital Vernier caliper with a precision of 0.01 mm to ensure accuracy and reproducibility of the data. All measurements were taken by the same observer to minimize interobserver variation.

Parameters Studied

The following morphometric and morphological parameters of the infraorbital foramen were studied bilaterally:

1. Transverse Diameter of Infraorbital Foramen

The maximum horizontal width of the infraorbital foramen was measured in millimeters.



2. Vertical Diameter of Infraorbital Foramen

The maximum vertical height of the infraorbital foramen was measured.

3. Distance between Infraorbital Foramen and Infraorbital Margin (IOF–IOM Distance)

The vertical distance from the upper margin of the infraorbital foramen to the infraorbital margin was measured.

4. Distance between Infraorbital Foramen and Anterior Nasal Spine (IOF–ANS Distance)
The linear distance between the center of the infraorbital foramen and the anterior nasal spine was recorded.

5. Distance between Infraorbital Foramen and Nasion (IOF–Na Distance)
The distance from the infraorbital foramen to the nasion was measured using the digital caliper.

6. Infraorbital Canal Length
To measure the length of the infraorbital canal using a flexible linear probe, first locate the external opening of the infraorbital foramen on the anterior surface of the maxilla.then gently guide a specialized flexible wire or probe backward, upward, and outward into the foramen, following the natural path of the canal until you see the tip emerge at the posterior exit point on the orbital floor where the closed canal meets the open infraorbital groove. While keeping the probe perfectly still at this exit boundary, you use a fine-tip marker to score the wire exactly where it touches the outermost margin of the external foramen. Finally, you carefully withdraw the probe from the skull and use a digital Vernier caliper to measure the exact distance between the tip of the wire and your ink mark, which gives you the total length of the canal in millimetres(6).

7. Shape of Infraorbital Foramen
The shape of the infraorbital foramen was observed visually and categorized as:

- Oval
- Round
- Triangular
- Irregular

8. Direction of Infraorbital Canal
The direction or orientation of the infraorbital canal was noted and classified as:

- Straight
- Inferomedial
- Inferolateral

To determine whether the opening direction of the infraorbital foramen is straight, inferomedial, or inferolateral, researchers use a standardized tactile and visual protocol based on how the foramen opens relative to the skull's vertical midline. A thin, completely rigid straight pin is gently inserted into the external opening of the foramen, allowing the bony walls of the exit rim to naturally dictate the angle at which the pin projects outward from the face. By looking directly at the skull from the front, the investigator classifies the direction by comparing the orientation of the protruding pin to the vertical mid-sagittal plane. The direction is classified as straight downward if the pin runs perfectly parallel to the midline, inferomedial if the pin tilts downward and inward toward the nose, and inferolateral if it tilts downward and outward toward the cheekbone(13)

9. Relative Position of Infraorbital Foramen to Supraorbital Foramen/Notch (SOF/N)
The alignment of the infraorbital foramen with respect to the supraorbital foramen or notch was studied to determine whether they were positioned in the same vertical plane.

10. Presence of Accessory Infraorbital Foramina
The skulls were examined for the presence of accessory infraorbital foramina, and their number and location were documented.

All observations and measurements were recorded systematically in a data collection sheet. Statistical analysis of the collected data was performed using jamove. Descriptive statistical methods including mean, standard deviation, frequency, and percentage were used to analyze the morphometric variables. The results were presented in tables and graphs wherever appropriate.

RESULTS

The present study evaluated the morphometric and morphological characteristics of the infraorbital foramen in 130 adult dry human skulls, comprising a total of 260 infraorbital foramina. Considerable anatomical variations were observed in relation to the dimensions, shape, direction, and accessory foramina.

Morphometric Measurements

The mean transverse diameter of the infraorbital foramen was found to be **2.93 ± 0.84 mm**, while the mean vertical diameter measured **3.09 ± 0.72 mm**. These findings indicate that the infraorbital foramen was slightly larger vertically than horizontally in most skulls examined.

The mean distance between the infraorbital foramen and the infraorbital margin (IOF–IOM distance) was **6.03 ± 1.83 mm**. This parameter is clinically significant for localizing the infraorbital nerve during infraorbital nerve block procedures and surgical interventions involving the orbital floor and midface.

The average distance between the infraorbital foramen and the anterior nasal spine (IOF–ANS distance) was **34.66 ± 3.30 mm**, whereas the mean distance from the infraorbital foramen to the nasion (IOF–Na distance) was **44.03 ± 4.62 mm**. These anatomical landmarks are useful reference points during maxillofacial reconstructive procedures and facial anthropometric studies.

The mean infraorbital canal length was observed to be **21.04 ± 2.40 mm**. Knowledge regarding the canal length is important during surgical exploration and decompression procedures involving the infraorbital nerve.

Morphometric Measurements

Parameter	Mean	SD	Min	Max
IOF Transverse Diameter(mm)	2.93	0.84	1.1	5.36
IOF Vertical Diameter(mm)	3.09	0.72	1.44	4.8
IOF–IOM Distance (mm)	6.03	1.83	2.5	11.0
IOF–ANS Distance (mm)	34.66	3.3	24.23	40.0
IOF–Na Distance (mm)	44.03	4.62	27.61	52.0
Infraorbital Canal Length (mm)	21.04	2.4	15.25	26.0

Shape of Infraorbital Foramen

Among the various morphological types observed, the **oval-shaped infraorbital foramen**was the most common finding. Round-shaped foramina constituted the next most common type, while triangular and irregular forms were observed less frequently. The predominance of the oval shape corresponds with findings reported in several previous anatomical studies(6).

IOF Shape

IOF Shape	Frequency	Percentage
Oval	154	59.23
Round	62	23.85
Triangular	44	16.92

Direction of Infraorbital Canal

The direction of the infraorbital canal showed variation among the studied skulls. The **straight orientation** was the predominant pattern observed in the majority of specimens. Inferomedial and inferolateral directions were less frequently encountered. Awareness of these directional variations is important for surgeons and anesthetists to avoid inadvertent injury to the infraorbital neurovascular bundle during invasive procedures.

IOF Direction

IOF Direction	Frequency	Percentage
Straight	157	60.38
Lateral	65	25.0
Medial	38	14.62

Relative Position to Supraorbital Foramen/Notch

In most skulls, the infraorbital foramen was located approximately in the same vertical plane as the supraorbital foramen or notch, although slight medial or lateral deviations were noted in some specimens. This relationship may serve as a useful surface landmark during clinical examination and regional anesthesia.

Relative Position to SOF/N

Relative Position to SOF/N	Frequency	Percentage

Aligned	111	42.69
Lateral	108	41.54
Medial	41	15.77

Accessory Infraorbital Foramina

Accessory infraorbital foramina were identified in a minority of skulls. These accessory openings may transmit additional branches of the infraorbital nerve and vessels. Failure to recognize such accessory foramina during surgical or anesthetic procedures may result in incomplete nerve block or persistent postoperative sensory disturbances.

The findings of the present study provide valuable morphometric and anatomical data regarding the infraorbital foramen in the South Indian population and may assist clinicians in improving the precision and safety of procedures involving the infraorbital region.

Accessory Foramen Present (Yes/No)

Accessory Foramen Present (Yes/No)	Frequency	Percentage
No	236	90.77
Yes	24	9.23

DISCUSSION

The infraorbital foramen is an important anatomical landmark in the maxillofacial region because it transmits the infraorbital nerve and vessels onto the face. Accurate knowledge regarding its morphology, morphometry, and anatomical variations is essential for clinicians performing infraorbital nerve blocks, facial reconstructive procedures, maxillofacial surgeries, orbital surgeries, rhinoplasty, and fracture fixation. Variations in the dimensions, location, and orientation of the infraorbital foramen may influence the effectiveness of local anesthesia and increase the risk of iatrogenic injury to the infraorbital neurovascular bundle. Therefore, morphometric evaluation of the infraorbital foramen has considerable clinical and surgical relevance.

In the present study, the mean transverse diameter of the infraorbital foramen was found to be 2.93 ± 0.84 mm, while the mean vertical diameter was 3.09 ± 0.72 mm. The vertical diameter was slightly greater than the transverse diameter, indicating that the infraorbital foramen tends to be vertically elongated in most skulls. Similar findings have been reported in previous anatomical studies conducted in Indian and other populations. The observed variations in dimensions may be attributed to racial, ethnic, genetic, environmental, and developmental factors. Knowledge of the average size of the infraorbital foramen is important during surgical exposure and placement of anesthetic needles to avoid neurovascular damage.

The mean distance between the infraorbital foramen and the infraorbital margin (IOF–IOM distance) in the present study was 6.03 ± 1.83 mm. This measurement is clinically significant because the infraorbital margin is one of the most commonly used palpable landmarks for locating the infraorbital foramen during infraorbital nerve block anesthesia. Comparable findings have been documented in studies conducted by Mahajan et al(6), Aggarwal et al(7)., and other investigators, although minor differences in measurements have been noted among various populations. Such differences may arise due to variation in craniofacial morphology among ethnic groups.

The mean distance between the infraorbital foramen and the anterior nasal spine (IOF–ANS distance) was 34.66 ± 3.30 mm, while the mean IOF–Na distance was 44.03 ± 4.62 mm. These anatomical measurements are useful reference parameters during maxillofacial reconstructive surgeries and facial anthropometric assessments. Surgeons frequently rely on these landmarks during procedures involving the orbital floor, maxillary sinus, and nasal region. Precise morphometric data help reduce operative complications and improve surgical outcomes.

In the present study, the mean infraorbital canal length was found to be 21.04 ± 2.40 mm. This parameter is particularly important during decompression procedures and surgical interventions involving the infraorbital nerve. Variations in canal length may influence the depth of needle insertion during nerve block administration and may affect the spread of local anesthetic agents within the canal(8).

Morphological analysis of the infraorbital foramen revealed that the oval shape was the most common type observed in the studied skulls. Round-shaped foramina were less common, while triangular and irregular shapes were relatively rare. The predominance of oval-shaped infraorbital foramina observed in the present study correlates with the findings of Mahajan et al(6)., Aggarwal et al(7)., and several other researchers. The variation in shape may be related to differences in ossification patterns and developmental anatomy of the maxilla. Awareness of these morphological variations is important because irregular or accessory foramina may complicate the localization of the infraorbital nerve during anesthesia and surgery.

The direction of the infraorbital canal was predominantly straight in the present study.

Inferomedial and inferolateral orientations were observed less frequently. Similar observations have been reported in earlier studies, suggesting that the straight orientation is the most common pattern in many populations(9). The orientation of the canal is clinically relevant because it determines the direction of needle advancement during infraorbital nerve block procedures. Failure to appreciate the canal direction may result in inadequate anesthesia or injury to the infraorbital nerve.

Accessory infraorbital foramina were identified in a minority of skulls examined in the present study. The presence of accessory foramina has important clinical implications because additional branches of the infraorbital nerve may emerge through these openings. Failure to recognize accessory foramina may lead to incomplete anesthesia, persistent postoperative pain, or unexpected bleeding during surgical procedures. Similar incidences of accessory infraorbital foramina have been documented in previous anatomical studies, although the reported frequency varies among populations(10).

The relationship of the infraorbital foramen to the supraorbital foramen or notch was also evaluated in the present study. In most skulls, the infraorbital foramen was approximately aligned vertically with the supraorbital foramen/notch. This anatomical relationship may aid clinicians in locating the infraorbital foramen using external facial landmarks during clinical examination and regional anesthesia. The findings of the present study contribute valuable morphometric data regarding the infraorbital foramen in the South Indian population. The study emphasizes the existence of anatomical variations in the size, shape, orientation, and number of infraorbital foramina. Such information is highly useful for anatomists, dentists, anesthetists, plastic surgeons, ophthalmologists, and maxillofacial surgeons in minimizing complications and improving the accuracy of diagnostic and therapeutic procedures involving the infraorbital region.

However, the present study has certain limitations. The skulls used were of unknown age and sex, and sex-based differences could not be evaluated. Additionally, soft tissue relations could not be assessed because the study was conducted on dry skulls. Further radiological and cadaveric studies with larger sample sizes may provide more comprehensive information regarding the infraorbital foramen and its clinical correlations.

Comparison with Previous Studies

Study	Population	TD	VD	IOF-IOM	IOF-ANS	IOF-Na	Accessory %	Shape
Present Study (2026)	South Indian	2.93	3.09	6.03	34.66	44.03	9.2	Oval
Mahajan et al., 2023	North Indian	2.5–2.6	3.8–3.9	5.8–6.2	34.2–34.3	42.2–42.3	NR	Oval
Nanayakkara et al., 2016	Sri Lankan	3.27–3.33	3.11–3.31	6.52–7.30	33.81–34.23	42.37–42.52	7.4	Oval
Gupta et al., 2018	South Indian	~3.0	~3.2	~6.1	Similar	Similar	NR	Oval
Indian Dry Skull Study, 2011	Indian	3.19–3.52	3.39–3.75	6.12–6.19	NR	NR	Rare	Vertical Oval
Bharti & Puranik	Indian	NR	NR	7.82	NR	NR	Present	Oval
Singh et al.	North Indian	NR	NR	Comparable	Measured	Measured	Evaluated	NR
CT Study, 2024	Indian CT	2.02	NR	7.35	NR	NR	NR	NR

- Transverse and vertical diameters are within published Indian ranges and close to South Indian reports.
- IOF-IOM distance of 6.03 mm supports use of the infraorbital margin as a reliable landmark.
- IOF-ANS distance is highly consistent with previous literature and may be the most dependable landmark.
- Accessory foramina prevalence of 9.2% lies within the reported global range.
- Oval shape remains the predominant morphology, consistent with most studies.
- IOF-Nasion distance appears slightly higher than several previous reports, suggesting regional variation.

Clinical Significance

The infraorbital foramen is a clinically important anatomical landmark because it transmits the infraorbital nerve and vessels onto the face. Detailed knowledge regarding its location, size, shape, direction, and anatomical variations is essential for clinicians involved in surgical, anesthetic, diagnostic, and reconstructive procedures involving the midfacial region. The morphometric findings of the present study have several important clinical applications.

One of the major clinical applications of the infraorbital foramen is in the administration of infraorbital nerve block anesthesia. The infraorbital nerve block is commonly performed during dental extractions, cleft lip and palate surgeries, treatment of facial lacerations, rhinoplasty, orbital surgeries, and other maxillofacial procedures. Accurate localization of the infraorbital foramen helps clinicians achieve effective regional anesthesia with minimal discomfort to the patient. Variations in the position or direction of the infraorbital canal may result in failed anesthesia or incomplete nerve blockade if not properly identified. Therefore, morphometric knowledge of the infraorbital foramen improves the precision and success rate of anesthetic procedures.

The present study is also clinically significant in preventing iatrogenic injury to the infraorbital nerve and accompanying vessels during surgical interventions. The infraorbital nerve is particularly vulnerable during procedures such as open reduction and internal fixation of facial fractures, orbital floor reconstruction, maxillary osteotomy, sinus surgeries, and cosmetic facial procedures(11). Accidental injury to the nerve may result in postoperative complications such as numbness, paresthesia, chronic pain, altered sensation, or loss of sensation involving the upper lip, cheek, lower eyelid, and lateral aspect of the nose. Awareness of anatomical variations, including accessory infraorbital foramina, can help surgeons avoid inadvertent neurovascular damage during operative procedures.

Knowledge of the infraorbital foramen is highly important in maxillofacial and reconstructive surgery. Surgeons frequently use the infraorbital margin and surrounding bony landmarks to identify the infraorbital foramen during facial reconstructive procedures and fracture management. Morphometric data regarding the IOF–IOM, IOF–ANS, and IOF–Na distances provide reliable anatomical reference points during surgical planning and operative navigation. Such information is especially useful during management of orbital blowout fractures, zygomaticomaxillary complex fractures, and craniofacial reconstructive surgeries.

The findings of the present study are also valuable for dentists and oral surgeons. Infraorbital nerve blocks are commonly administered in dental practice for procedures involving the maxillary anterior teeth, premolars, and associated soft tissues. Anatomical variations in the infraorbital foramen may explain failure of local anesthesia in certain patients. Detailed morphometric knowledge helps dental practitioners perform safer and more effective anesthetic techniques.

Radiologists may also benefit from the present study while interpreting radiographic and computed tomography (CT) images of the maxillofacial region. Accessory infraorbital foramina or unusual positions of the infraorbital canal may sometimes be misinterpreted as pathological lesions or fractures. Awareness of normal anatomical variations can improve radiological diagnosis and prevent diagnostic errors.

For anatomists and medical educators, the present study contributes valuable baseline anatomical data regarding the infraorbital foramen in the South Indian population. Such population-specific data are important for anatomical teaching, anthropological studies, forensic identification, and future research involving craniofacial anatomy.

Overall, the morphometric and morphological knowledge obtained from the present study has significant practical implications for anesthetists, dentists, radiologists, plastic surgeons, ophthalmologists, and maxillofacial surgeons. A thorough understanding of infraorbital foramen anatomy can improve procedural accuracy, reduce complications, and enhance patient safety during diagnostic and therapeutic interventions involving the infraorbital region.

CONCLUSION

The infraorbital foramen is an important anatomical structure of the maxillofacial region that demonstrates significant variations in its morphology and morphometry. The present study revealed considerable variation in the size, shape, direction, position, and occurrence of accessory infraorbital foramina in adult dry human skulls. Oval-shaped infraorbital foramina were found to be the most common morphological type, and the straight orientation of the infraorbital canal was the predominant pattern observed. The study also established important morphometric parameters, including the transverse and vertical diameters of the infraorbital foramen, its distance from the infraorbital margin, anterior nasal spine, and nasion, as well as the length of the infraorbital canal.

These findings provide valuable baseline anatomical data regarding the infraorbital foramen in the South Indian population. Since anatomical variations may differ among ethnic and regional populations, such population-specific morphometric information is essential for improving the safety and effectiveness of clinical procedures involving the infraorbital region.

The morphometric data obtained in the present study have significant clinical applications in infraorbital nerve block anesthesia, maxillofacial surgery, reconstructive facial procedures, orbital surgeries, rhinoplasty, dental interventions, and management of facial trauma. Accurate knowledge of the location and anatomical variations of the infraorbital foramen can help clinicians avoid iatrogenic injury to the infraorbital nerve and vessels, reduce operative complications, improve surgical precision, and increase the success rate of anesthetic procedures.

The study also highlights the importance of recognizing accessory infraorbital foramina and variations in canal direction, as failure to identify these variations may lead to incomplete anesthesia, persistent postoperative sensory disturbances, or neurovascular injury. The relationship of the infraorbital foramen to surrounding anatomical landmarks further enhances its utility as a reliable guide during clinical and surgical procedures.

Overall, the present study contributes clinically relevant anatomical information that may be beneficial to anatomists, dentists, anesthetists, radiologists, plastic surgeons, ophthalmologists, and maxillofacial surgeons. The findings enrich existing anatomical literature and may serve as a useful reference for future research in craniofacial anatomy and surgical anatomy. Further studies involving larger sample sizes, radiological imaging, and sex-based comparisons may provide additional insights into the anatomical variations of the infraorbital foramen and their clinical implications.

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