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Clinical Anatomy

A MORPHOLOGICAL AND MORPHOMETRIC COMPARATIVE STUDY OF THE INFRAORBITAL FORAMEN IN DRY HUMAN SKULLS AND THREE-DIMENSIONAL COMPUTED TOMOGRAPHIC IMAGES

Dr. A. Bharathivelan* — Assistant Professor, Department of Anatomy *Corresponding Author

Dr. T. Saranraj — Assistant Professor, Department of Radiodiagnosis

Dr. R. Raamadas — Senior Resident, Department of Anatomy

ABSTRACT **Background:** The infraorbital foramen (IOF) is an important anatomical landmark on the anterior surface of the maxilla that transmits the infraorbital neurovascular bundle. Precise localization of the IOF is essential during maxillofacial surgery, orbital reconstruction, infraorbital nerve block, dental procedures, and facial trauma management. Although numerous osteological and radiological studies have described its morphology and morphometry, comparative evaluation between dry skulls and three-dimensional computed tomography (CT) remains limited. **Aim:** To compare the morphological and morphometric characteristics of the infraorbital foramen in dry human skulls and three-dimensional reconstructed CT images and evaluate their clinical significance. **Materials and Methods:** A comparative cross-sectional study was conducted using 100 adult dry human skulls (200 foramina) and 100 three-dimensional reconstructed CT skull images (200 foramina). Morphological characteristics including shape, direction of opening, presence of accessory foramina, and site of accessory foramina were recorded. Morphometric parameters included the maximum vertical and transverse diameters of the IOF and its distance from selected anatomical landmarks, namely the nasion, anterior nasal spine, infraorbital margin, lower alveolar margin, canine fossa, inferior orbital fissure, optic canal, superior orbital fissure, and supraorbital foramen. Statistical analysis was performed using IBM SPSS Statistics version 29.0. Independent sample t-tests and Chi-square tests were applied, with $p < 0.05$ considered statistically significant. **Results:** Oval-shaped infraorbital foramina were the most common morphological variant in both groups. Inferomedial opening was the predominant direction. Accessory infraorbital foramina were identified in approximately 15% of specimens. Comparison of morphometric measurements revealed statistically significant differences between dry skulls and CT skulls for most parameters; however, the absolute differences were minimal, indicating good agreement between both methods. **Conclusion:** Three-dimensional CT provides morphometric measurements that closely correspond to direct osteometric observations. The findings provide clinically useful anatomical data for surgeons, anaesthesiologists, dentists, radiologists, and forensic experts performing procedures involving the midface.

KEYWORDS : Infraorbital Foramen; Morphometry; Dry Skull; Computed Tomography; Maxillofacial Surgery; Infraorbital Nerve Block.

INTRODUCTION

The infraorbital foramen (IOF) is located on the anterior surface of the maxilla below the infraorbital margin and represents the terminal opening of the infraorbital canal. It transmits the infraorbital nerve, artery, and vein, which supply the lower eyelid, upper lip, lateral nose, cheek, and adjacent facial soft tissues (Standring, 2021). Owing to its close relationship with several surgical approaches to the midface, accurate localization of the IOF is essential for preventing neurovascular injury and ensuring successful regional anesthesia.

The infraorbital nerve, a continuation of the maxillary division of the trigeminal nerve (CN V2), is frequently targeted during infraorbital nerve block for maxillofacial surgeries, cleft lip repair, orbital procedures, facial fracture fixation, dental interventions, and cosmetic surgery. Failure to accurately identify the infraorbital foramen may result in incomplete anesthesia, hemorrhage, postoperative paraesthesia, or persistent neuropathic pain (Moore et al., 2023). Consequently, understanding anatomical variations of the IOF has considerable clinical relevance.

The morphology of the infraorbital foramen varies among different populations with respect to its size, shape, direction of opening, and number of accessory foramina. Such variations are attributed to ethnic diversity, developmental factors, sexual dimorphism, and craniofacial morphology (Ilayaperuma et al., 2010). Previous osteological studies have demonstrated that the IOF may be oval, round, semilunar, vertically oval, or horizontally oval. Similarly, accessory infraorbital foramina have been reported in 5–20% of skulls and may transmit additional branches of the infraorbital nerve, thereby influencing the effectiveness of local aesthetic techniques (Kazkayasi et al., 2001).

Morphometric evaluation of the IOF has traditionally been performed using dry human skulls because direct osteometric measurements provide excellent anatomical accuracy. However, advances in multidetector computed tomography (MDCT) and three-dimensional reconstruction have enabled precise, non-invasive evaluation of craniofacial anatomy. Three-dimensional CT imaging has become an indispensable component of preoperative planning for maxillofacial surgery, orbital reconstruction, image-guided navigation, and forensic anthropology (Macedo et al., 2009).

Although numerous studies have independently evaluated dry skulls or CT images, comparative investigations involving both modalities remain limited. Establishing agreement between osteometric and radiological measurements is important for validating CT-based morphometry in routine clinical practice. Reliable CT measurements may reduce the need for invasive anatomical assessment while improving surgical planning and patient safety.

The present study was therefore undertaken to compare the morphology and morphometry of the infraorbital foramen in dry human skulls and three-dimensional reconstructed CT images. The findings are expected to provide clinically relevant anatomical data that may facilitate infraorbital nerve block, maxillofacial reconstruction, orbital surgery, dental implant placement, and other procedures involving the midfacial region.

Aim

To compare the morphological and morphometric characteristics of the infraorbital foramen in dry human skulls and three-dimensional reconstructed CT images and evaluate their clinical significance.

Objectives

1. To evaluate the morphology of the infraorbital foramen in dry skulls and CT skull images.
2. To determine the shape, direction of opening, and presence of accessory infraorbital foramina.
3. To measure the maximum vertical and transverse diameters of the infraorbital foramen.
4. To determine the distance between the infraorbital foramen and adjacent anatomical landmarks.
5. To compare morphometric measurements between dry skulls and CT skull images.
6. To assess the clinical relevance of infraorbital foramen variations in surgical and radiological practice.

MATERIALS AND METHODS

A comparative cross-sectional observational study was conducted in the Department of Anatomy in collaboration with the Department of Radiodiagnosis after obtaining Institutional Ethics Committee approval (Approval No. 218/SVMCH/IEC-Cert/Dec.25). The study included 100 adult dry human skulls and 100 archived three-

dimensional reconstructed CT skull images, representing a total of 400 infraorbital foramina.

Adult skulls with intact maxillae, preserved orbital margins, and clearly identifiable infraorbital foramina were included. Skulls showing fractures, deformities, pathological lesions, or damage to the maxillofacial region were excluded. CT images included adults above 18 years of age with high-quality craniofacial scans and complete visualization of both infraorbital foramina. Patients with craniofacial anomalies, previous facial surgery, fractures, or poor-quality scans were excluded.

Morphological observations included the shape of the infraorbital foramen, direction of opening, presence of accessory foramina, and their anatomical location. Morphometric measurements were obtained using a digital Vernier caliper for dry skulls and electronic measuring tools on DICOM software for CT images. Measurements included maximum vertical diameter, maximum transverse diameter, and distances from the infraorbital foramen to the nasion, anterior nasal spine, infraorbital margin, lower alveolar margin, canine fossa, inferior orbital fissure, optic canal, superior orbital fissure, and supraorbital foramen. Angular orientation of the infraorbital canal was also recorded. Each measurement was repeated three times and the average value was used for analysis to minimize observer error.

Statistical analysis was performed using IBM SPSS Statistics version 29.0. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were expressed as frequency and percentage. Independent sample t-tests were used to compare morphometric measurements between dry skulls and CT skulls, while Chi-square tests were applied for categorical variables. A p-value < 0.05 was considered statistically significant.

Figure 1. Dry Skull Showing the Infraorbital Foramen.

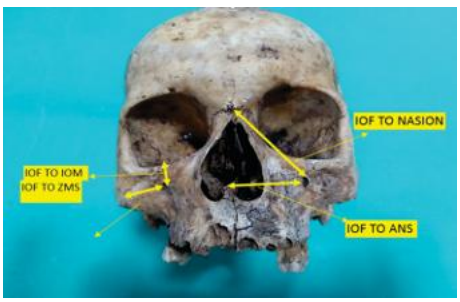

Figure 2. Measurements of the Infraorbital Foramen

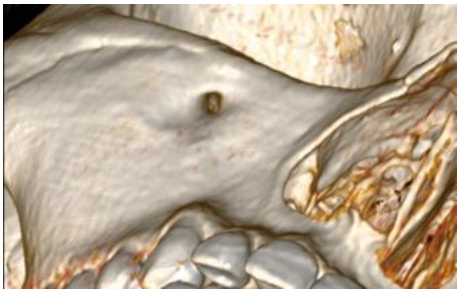

Figure 3. Three-dimensional Reconstructed CT Skull Demonstrating the Infraorbital Foramen.

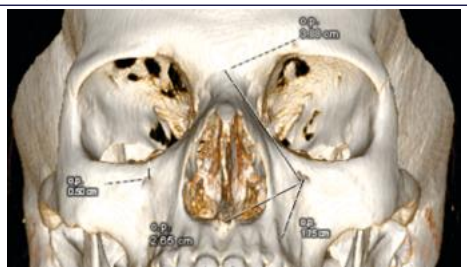

Figure 4. Three-dimensional CT Image Demonstrating Morphometric Measurements.

RESULTS

A total of 100 dry human skulls and 100 three-dimensional reconstructed CT skull images were included in the study, representing 400 infraorbital foramina. Both right and left sides were evaluated independently.

The oval-shaped infraorbital foramen was the predominant morphological variant in both study groups, followed by round and semilunar shapes. Inferomedial opening was the most common direction observed. Accessory infraorbital foramina were identified in approximately 15% of specimens, with the majority located superomedial to the principal foramen. No statistically significant differences were observed between dry skulls and CT images regarding the distribution of shape, direction of opening, or accessory foramina ($p > 0.05$).

Morphometric comparison between dry skulls and CT skulls is presented in Table 1. Statistically significant differences were observed for the maximum vertical diameter, maximum transverse diameter, distance to the nasion, anterior nasal spine, infraorbital margin, lower alveolar margin, canine fossa, inferior orbital fissure, optic canal, superior orbital fissure, supraorbital foramen, and angular measurement ($p < 0.05$). Nevertheless, the absolute differences between the two modalities were minimal, indicating close agreement between direct osteometry and CT-based measurements.

Table 1. Comparison of Morphometric Measurements Between Dry Skull and CT Skull

Parameter	Dry Skull (Mean ± SD)	CT Skull (Mean ± SD)	p-value
Maximum Vertical Diameter (cm)	0.22 ± 0.03	0.21 ± 0.04	0.031
Maximum Transverse Diameter (cm)	0.18 ± 0.03	0.19 ± 0.03	0.042
Distance to Nasion (cm)	4.41 ± 0.18	4.48 ± 0.23	0.007
Distance to Anterior Nasal Spine (cm)	2.87 ± 0.19	2.92 ± 0.22	0.020
Distance to Infraorbital Margin (cm)	0.81 ± 0.11	0.85 ± 0.14	0.004
Distance to Lower Alveolar Margin (cm)	2.69 ± 0.21	2.75 ± 0.25	0.034
Distance to Canine Fossa (cm)	2.12 ± 0.18	2.19 ± 0.22	0.011
Distance to Inferior Orbital Fissure (cm)	2.10 ± 0.17	2.16 ± 0.20	0.016
Distance to Optic Canal (cm)	3.77 ± 0.24	3.85 ± 0.26	0.014
Distance to Superior Orbital Fissure (cm)	3.89 ± 0.23	3.95 ± 0.26	0.045
Distance to Supraorbital Foramen (cm)	2.61 ± 0.22	2.68 ± 0.26	0.021
Angular Measurement (°)	53.9 ± 9.8	55.9 ± 11.8	0.032

Male skulls generally demonstrated larger morphometric measurements than female skulls, particularly for the maximum vertical diameter, distance to the nasion, and distance to the optic canal. However, bilateral comparison revealed no significant differences between the right and left sides.

DISCUSSION

The infraorbital foramen is a key anatomical landmark used in maxillofacial surgery, regional anesthesia, orbital reconstruction, and facial trauma management. Accurate knowledge of its morphology and morphometry is essential to minimize neurovascular injury and improve surgical precision. The present study compared osteometric measurements obtained from dry human skulls with three-dimensional

CT images and demonstrated good agreement between the two modalities.

The oval shape was the predominant morphology observed in both groups, consistent with previous studies by Aziz et al. (2000), Ilayaperuma et al. (2010), and Egabaram et al. (2014). This suggests that the developmental pattern of the infraorbital canal remains relatively constant across populations. Similarly, the inferomedial direction of opening was the most frequent orientation, supporting the findings of Kazkayasi et al. (2001). Recognition of this orientation is important during infraorbital nerve block because needle direction should follow the natural course of the infraorbital canal to improve anaesthetic success and reduce complications.

Accessory infraorbital foramina were identified in approximately 15% of specimens, which is comparable with previous reports ranging from 10% to 18% (Berry, 1975; Cutright et al., 2003). These accessory foramina may transmit additional branches of the infraorbital nerve, explaining occasional failure of conventional infraorbital nerve blocks. Their identification on preoperative CT scans may therefore assist surgeons and anaesthesiologists in modifying surgical approaches and anaesthetic techniques.

Comparison of morphometric measurements demonstrated statistically significant differences between dry skulls and CT skulls for several parameters. However, these differences were numerically small and are unlikely to influence clinical decision-making. Similar observations have been reported by Macedo et al. (2009) and Lopes et al. (2019), who concluded that multidetector CT provides measurements closely corresponding to direct anatomical observations. Minor discrepancies may result from image reconstruction algorithms, slice thickness, observer variation, and differences in measurement techniques rather than true anatomical variation.

The present study also demonstrated minimal side-to-side variation, indicating bilateral symmetry of the infraorbital foramen. Similar findings have been described in South Indian, Sri Lankan, Brazilian, and Thai populations, suggesting that the anatomical position of the infraorbital foramen remains relatively constant irrespective of laterality. Male skulls exhibited slightly larger measurements than female skulls, reflecting general sexual dimorphism in craniofacial dimensions. Nevertheless, considerable overlap between sexes indicates that clinical localization should rely primarily on anatomical landmarks rather than sex-specific estimates.

A major strength of this study is the inclusion of both direct osteometric measurements and CT-based morphometry using standardized anatomical landmarks. Comparative evaluation of these modalities provides evidence supporting the reliability of three-dimensional CT for preoperative planning. The findings are particularly relevant for orbital floor reconstruction, zygomatic fracture fixation, Le Fort osteotomies, infraorbital nerve decompression, rhinoplasty, and dental implant placement.

Clinical Significance

The morphometric data generated in the present study have direct clinical relevance. Accurate localization of the infraorbital foramen improves the success of infraorbital nerve block and reduces the risk of injury to the infraorbital neurovascular bundle during facial surgery. Identification of accessory infraorbital foramina is particularly important because accessory nerve branches may contribute to incomplete anaesthesia if unrecognized. Three-dimensional CT imaging provides reliable preoperative assessment and should be considered during planning of maxillofacial, orbital, and cosmetic surgical procedures.

Limitations

The study was limited by the use of dry skulls of unknown age and the inclusion of CT images from a single institution. Interobserver variability was not evaluated. Future multicentred studies incorporating larger and ethnically diverse populations may provide more comprehensive morphometric data.

CONCLUSION

The infraorbital foramen demonstrated relatively consistent morphology and morphometry in both dry human skulls and three-dimensional CT images. Oval-shaped foramina with inferomedial orientation were the predominant findings, while accessory infraorbital foramina were observed in a minority of specimens. Although statistically significant differences were identified for several morphometric parameters, the differences were small, confirming that three-dimensional CT provides measurements comparable to direct osteometric assessment. These findings support the use of CT imaging as a reliable tool for preoperative localization of the infraorbital foramen and may contribute to safer and more effective maxillofacial, dental, ophthalmic, and reconstructive procedures.

Declarations:
Ethical Approval: Obtained from the Institutional Ethics Committee (Approval No. 218/SVMCH/IEC-Cert/Dec.25).
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Conflict of Interest: The authors declare no conflict of interest.

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