Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2025;42:103-112

Morphological Study of Infraorbital Foramen in Dry Human Skulls in Northeastern Brazil

João Paulo de Oliveira Jerônimo Rodrigues[1], Alexandre Casusão de Sousa[1], João Vitor Andrade Fernandes[1], Lucas Brito Meira[1], Emmily Neves de Araújo Pereira[1], Reynaldo de França Souza[2], Jalles Dantas de Lucena[3], André de Sá Braga Oliveira[4]

[1]Medical School, Federal University of Paraiba (UFPB). Universidade Federal da Paraíba, João Pessoa, PB, Brazil
[2]Nursing School, Federal University of Paraiba (UFPB). Universidade Federal da Paraíba, João Pessoa, PB, Brazil
[3]Santa Maria University Center (UNIFSM), Medicine Course, Cajazeiras, PB, Brazil
[4]Department of Morphology, Federal University of Paraiba (UFPB). João Pessoa, PB, Brazil

Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT

Introduction: The infraorbital foramen (IOF) is a critical anatomical structure within the maxillary bone, serving as a conduit for neurovascular elements. Purpose: This study aims to elucidate the precise location and morphology of the IOF to enhance surgical and procedural accuracy in the midface region, thereby assisting medical and dental practitioners.
Materials and Methods: This study analyzed 140 IOFs from 70 dry skulls (23 male and 47 female) housed in the Department of Morphology at the Federal University of Paraíba. Parameters documented included IOF shape, aperture direction, presence and position of accessory IOFs (AIOFs), and 12 craniometric measurements. Data analysis considered p<0.05 as significant.
Results: The IOF predominantly exhibited an oval (44.2%) and round shape (42.8%) with a majority of apertures oriented medially downwards (49%). Accessory IOFs were identified in 22% of the skulls analyzed, with the superomedial position being the most common (86.9%). Craniometric analysis revealed that measurements in females were consistently lower than in males, with no significant right-left dominance observed, except for the HD, which was larger on the left side than on the right side.
Conclusion: This study was the first to analyze the IOF and AIOF in Paraíba, Northeastern Brazil. These findings can improve the accuracy of medical, dental, and aesthetic procedures by aiding in the precise localization of the IOF in the population studied.
Keywords: Infraorbital foramen; Skull; Craniometric distance; Neurovascular; Maxillary bone.

Introduction

The infraorbital foramen (IOF) is a bony foramen, located in the maxillary bone, positioned inferiorly to the orbital cavity, laterally to the nasal cavity, medially to the zygomatic arch and superiorly to the alveolar processes of the maxilla[1].

The IOF is an important structure in the infraorbital region, as it allows the passage of vascular and nervous structures for the arterial and venous supply and sensory innervation of parts of the face[2]. Through the IOF pass: the infraorbital vein (IOV), the infraorbital artery (IOA) and the infraorbital nerve (ION), which will divide into four branches, forming the cruciform bouquet of the infraorbital region, innervating the lower eyelid, the wing of the nose, the upper lip, upper incisors, canines and premolar teeth and the genial region[3].

Knowledge of the location of the IOF is essential when carrying out procedures such as local anesthesia and oral, maxillary and plastic surgeries, in order to avoid injuries to the structures that pass through it[4]. Currently, the study of IOF assists in the development of medical, dental and dermatological procedures which normally require anesthesia of the labiogenial, lateral nasal and eyelid regions.

Therefore, due to the importance of the IOF and the structures that pass through it, added to the lack of information in the literature from Brazil, the objective of this work was to morphometrically analyze the infraorbital foramen and its anatomical variations in dry skulls from Northeastern Brazil, in order to allow more precise knowledge to professionals who work with this body region.

Materials and Methods

The present study was approved by the Research Ethics Committee of the Health Sciences Center of the Federal University of Paraíba (protocol number: 68587723.8.0000.5188). This study analyzed dry skulls from Northeastern Brazil, with unknown ages, belonging to the Human Anatomy Laboratory at the Federal University of Paraíba (UFPB). Only dry, non-childlike and undamaged skulls were analyzed. The sexing of the skulls was documented using anthropometric standards by two independent, well-trained technicians[5].

The shape of the infraorbital foramen (IOF) was categorized into triangular, round, oval, or semilunar shapes[6]. Evaluation included the orientation of the infraorbital canal opening, classified as medially

DOI: 10.51929/jms.42.103.2025
ISSN 2177-0298

downwards, medially, or downwards[3], as well as the presence, laterality, and relative position of any accessory infraorbital foramen.

Subsequently, a morphometric analysis was conducted using a Starfer® caliper (João Pessoa, Paraíba, Brazil) with an accuracy of up to 0.02 mm. Measurements were taken as follows: vertical distance from the center of the upper margin of the IOF to the infraorbital margin (IOF-A); distance from the center of the medial margin of the IOF to the lateral edge of the piriform aperture (IOF-B); vertical distance from the center of the lower margin of the IOF to the alveolar border (IOF-C). Additionally, vertical (VD) and horizontal (HD) diameters of the IOF were recorded (Figure 1).

Figure 1. Anterior view of the skull presenting the morphometric parameters analyzed in the study.
Legend: IOF-A: vertical distance from the center of the upper margin of the IOF to the infraorbital margin; IOF-B: from the center of the medial margin of the IOF to the lateral edge of the piriform aperture; IOF-C: vertical distance from the center of the lower margin of the IOF to the alveolar border; HD: horizontal diameter; VD: vertical diameter.

Further measurements included: distance from the most anterior point of the anterior nasal spine (ANS) to the lowest point of the zygomaticomaxillary suture (ZS) (A), distance from the mid-upper edge of the IOF to line A (B), horizontal distance from ANS to the point where the vertical line of IOF intersects with line A (C) and vertical distance from the mid-superior edge of the accessory infraorbital foramen (AIOF) to line A (D) (Figure 2). The vertical distance between IOF and AIOF (E), the horizontal distance between IOF and AIOF (F) and the distance between the mid-superior edge of the AIOF and the mid-superior edge of the IOF (G) were also measured (Figure 3).

The most recent version of Word and Excel were used to record the qualitative and quantitative

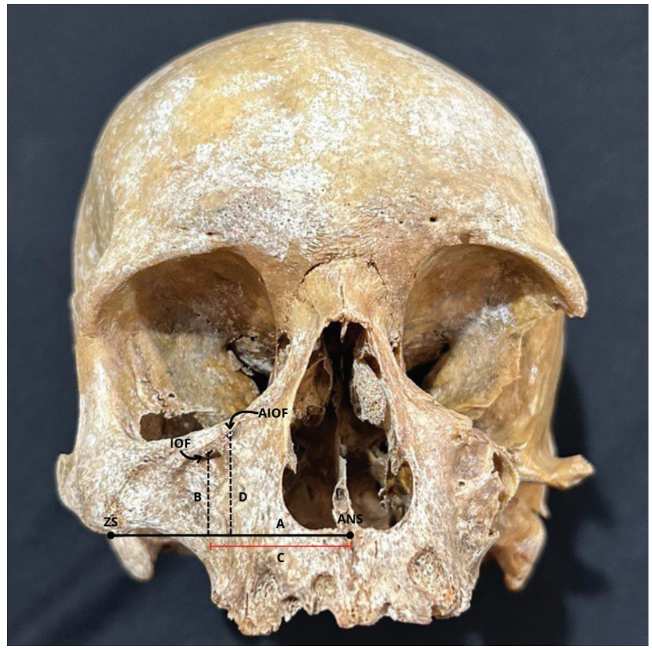

Figure 2. Anterior view of the skull presenting the morphometric parameters analyzed in the study.
Legend: ANS: anterior nasal spine; ZS: zygomaticomaxillary suture; IOF: infraorbital foramen; AIOF: accessory infraorbital foramen; A: distance between the most anterior point of the ANS to the lowest point of the ZS; B: Distance from the mid-upper edge of the IOF to line A; C: horizontal distance from ANS to the point of intersection of the IOF vertical line with line A; D: Vertical distance from the mid-superior edge of the accessory infraorbital foramen (AIOF) to line A.

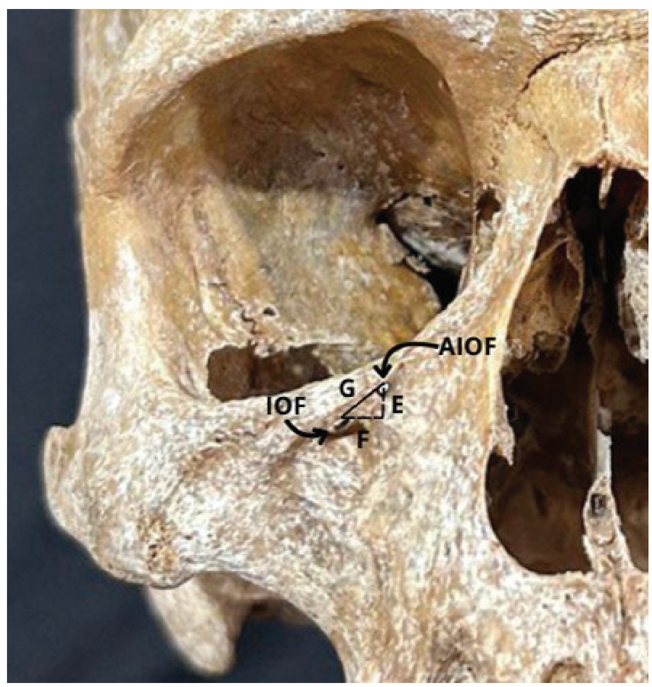

Figure 3. Anterior view of the skull presenting the morphometric parameters analyzed in the study.
Legend: IOF: infraorbital foramen; AIOF: accessory infraorbital foramen; E: vertical distance between IOF and AIOF; F: horizontal distance between IOF and AIOF; G: distance between the mid-superior edge of the AIOF and the mid-superior edge of the IOF.

analysis. For statistical analysis of the data, Jamovi version 2.3.24 was used. Shapiro-wilk Test was used for testing the normality of the sample. Comparison was done between genders and between right and left antimeres by t-Test for independent samples with p>0.05 on Shapiro-wilk Test and Mann-Whitney Test was used for independent samples with p<0.05. Values of $p < 0.05$ were considered significant on comparison.

Results

Seventy dry skulls were included in the analysis, 23 (32%) male and 47 (67%) female, corresponding to 140 IOF.

The description of the shape of the infraorbital foramen in this study was summarized in Table 1. In the total sample, 60 foramina with a round shape, 14 with a triangular shape, 62 with an oval shape and 4 with a semilunar shape were observed (42.8%, 10%, 44.2% and 2.8%, respectively). Regarding the shape of the IOF by sex, in male skulls, on both sides, 10 foramina had a round shape, 3 foramina had a triangular shape, 10 foramina had an oval shape, and none had a semilunar shape (7.1%, 2.1%, 7.1% and 0%, respectively). In female skulls, on both sides, 20 foramina were round shape, 4 were triangular shape, 21 were oval shape and 2 were semilunar shape (14.3%, 2.9%, 15% and 1.4%, respectively).

Table 2 represents the description of the direction of the infraorbital foramen opening. In the total sample, the medially downward direction was observed in 69 foramina, the medially direction was observed in 43 foramina, and the downward direction was observed in 28 foramina (49%, 31%, and 20%, respectively). Regarding the direction of opening of the IOF by sex, in male skulls, it was observed that, on both sides, 14 foramina presented a medially downward opening direction (10%), 4 foramina presented a downward opening direction (2.9%), and 5 foramina presented a medial opening direction (3.6%). In female skulls, 20 foramina opened medially downwards on the right side and 21 on the left side (14.3% and 15%, respectively); 10 foramina presented, on both sides, a downward opening direction (7.1%) and 17 foramina presented a medial opening direction on the right side and 16 on the right side (36% and 34%, respectively).

Regarding the position of the Accessory Infraorbital Foramen (AIOF), it was present 23 times in the evaluated skulls, being 7 bilateral, 2 right unilateral and 7 left unilateral, i.e. present in 16 skulls (22% of the total skull sample). Eight (8) AIOF were observed in male skulls, 3 of them on the right side and 5 on the left side (13% and 22% of the total AIOF found in the study, respectively). In female skulls, 15 AIOF were observed, 6 on the right side and 9 on the left side (26% and 39% of the total AIOF, respectively). Furthermore, no presence nor absence was recorded on the right side of one of the female skulls due to the deterioration of the piece, which made it difficult to define the AIOF (Table 3).

Regarding the position of the AIOF in relation to the IOF, all the eight (8) AIOF of male skulls presented a superomedial position. In females, five (5) foramina were in a superomedial position on the right side and seven (7) on the left side; One (1) foramen on the right side and one (1) on the left side presented a superior position; and one (1) foramen on the left side presented an inferomedial position (Table 3).

Table 1. Percentage distribution of infraorbital foramen shape in skulls from Northeastern Brazil (N=70)

Shape - IOF	Male skulls		Female skulls		TOTAL
	Right	Left	Right	Left	
Round	10 (7.1%)	10 (7.1%)	20 (14.3%)	20 (14.3%)	60 (42.8%)
Triangular	3 (2.1%)	3 (2.1%)	4 (2.9%)	4 (2.9%)	14 (10%)
Oval	10 (7.1%)	10 (7.1%)	21 (15%)	21 (15%)	62 (44.2%)
Semilunar	0 (0%)	0 (0%)	2 (1.4%)	2 (1.4%)	4 (2.8%)
TOTAL	46 (32.6%)		94 (67.2%)		140 (100%)

N = total number of IOF analyzed in the study; % = percentage distribution in relation to the total IOF sample.

Table 2. Percentage distribution of the direction of opening of the infraorbital foramen (IOF) in skulls from Northeastern Brazil.

Direction of opening - IOF	Male skulls		Female skulls		TOTAL
	Right	Left	Right	Left	
Downwards	4 (2.9%)	4 (2.9%)	10 (7.1%)	10 (7.1%)	28 (20%)
Medially downwards	14 (10%)	14 (10%)	20 (14.3%)	21 (15%)	69 (49%)
Medially	5 (3.6%)	5 (3.6%)	17 (12.1%)	16 (12.1%)	43 (31%)
TOTAL	46 (33%)		94 (67%)		140 (100%)

N = total number of IOF analyzed in the study; % = percentage distribution in relation to the total IOF sample.

Table 3. Incidence and Position of Accessory Infraorbital Foramen (AIOF) in skulls from Northeastern Brazil (N=23).

Position of the AIOF	Male skulls		Female skulls		TOTAL
	Right	Left	Right	Left	
Superior	0 (0%)	0 (0%)	1 (4.35%)	1 (4.35%)	2 (8.7%)
Superomedial	3 (13.04%)	5 (21.74%)	5 (21.74%)	7 (30.43%)	20 (86.9%)
Inferomedial	0 (0%)	0 (0%)	0 (0%)	1 (4.35%)	1 (4.35%)
TOTAL	8 (34.78%)		15 (65.22%)		23 (100%)

N = total number of AIOF found in the study. % = Percentage distribution of the AIOF in relation to the total AIOF found in this study.

Table 4 represents the mean or median distance from the morphometric analysis of the antimeres of the infraorbital foramen, without comparing sexes. The horizontal diameter (HD) was shown to be larger on the left side compared to the right side in the total sample as well as in both male and female skulls ($p<0.05$). No differences were observed in the other morphometric parameters evaluated.

The mean or median distance from the analysis of sexual dimorphism of the infraorbital foramen is represented in Table 5. When comparing the right side between sexes, the measurements IOF-C, A, and C were found to be larger in males ($p<0.05$). Regarding the left side, the measurements IOF-A, IOF-C, HD, A, and C were larger in males ($p<0.05$). In the total sample, the measurements IOF-A, IOF-B, IOF-C, HD,

Table 4. Mean or Median distance (mm) ± SD or IQR values of the morphometric analysis of the infraorbital foramen antimers.

Measurements	Total Sample N = 140			Male N = 46			Female N = 94		
	Right	Left	*p-value*	Right	Left	*p-value*	Right	Left	*p-value*
IOF-A	6.50 (2.05) †	6.68 (1.83) †	**0.36** †	6.94 (2.14) †	7.59 (1.70) †	**0.55** †	6.24 (2.13) †	6.47 (1.59) †	**0.39** †
IOF-B	14.62 (1.80)	15.03 (2.08)	**0.21**	15.06 (1.50)	15.71 (2.10)	**0.23**	14.40 (1.90)	14.69 (2.01)	**0.47**
IOF-C	26.85 (4.55)	26.69 (4.32)	**0.84**	29.63 (4.39)	29.20 (4.35)	**0.74**	25.46 (3.99)	25.52 (3.82)	**0.94**
HD	2.77 (0.80) †	3.09 (0.79) †	**<0.001** * †	2.99 (0.56)	3.46 (0.55)	**0.007** **	2.62 (0.74) †	2.98 (0.71) †	**0.006** * †
VD	3.48 (0.72)	3.38 (0.72)	**0.40**	3.71 (0.61)	3.58 (0.63)	**0.48**	3.37 (0.75)	3.28 (0.75)	**0.56**
A	52.06 (5.34) †	52.61 (4.59) †	**0.20** †	54.04 (3.03)	54.75 (2.96)	**0.43**	50.30 (4.60) †	51.38 (4.67) †	**0.34** †
B	14.42 (3.56) †	13.81 (3.65) †	**0.57** †	15.17 (2.44)	15.01 (2.53)	**0.83**	14.01 (3.55) †	13.29 (3.24) †	**0.46** †
C	29.27 (2.61)	29.92 (2.55)	**0.14**	31.17 (2.19) †	31.40 (3.47) †	**0.27** †	28.81 (2.31)	29.22 (2.57)	**0.42**
D	20.28 (2.11)	18.65 (4.20)	**0.29**	19.85 (0.99)	19.23 (3.84)	**0.80**	20.50 (2.57)	18.33 (4.57)	**0.31**
E	6.97 (4.83) †	5.71 (4.23) †	**0.14** †	8.74 (4.08)	5.58 (4.24)	**0.34**	6.74 (1.50) †	5.84 (4.41) †	**0.33** †
F	7.94 (4.02)	7.20 (3.41)	**0.64**	8.43 (4.67)	6.12 (3.09)	**0.42**	7.69 (4.11)	7.79 (3.61)	**0.96**
G	11.61 (9.63) †	7.78 (5.90) †	**0.12** †	13.16 (5.59)	8.30 (5.12)	**0.25**	9.82 (8.12) †	7.91 (4.54) †	**0.46** †

IOF-A: vertical distance from the center of the upper margin of the IOF to the infraorbital margin; IOF-B: from the center of the medial margin of the IOF to the lateral edge of the piriform aperture; IOF-C: vertical distance from the center of the lower margin of the IOF to the alveolar border; HD: horizontal diameter; VD: vertical diameter; A: distance between the most anterior point of the ANS to the lowest point of the ZS; B: Distance from the mid-upper edge of the IOF to line A; C: horizontal distance from ANS to the point of intersection of the IOF vertical line with line A; D: Vertical distance from the mid-superior edge of the accessory infraorbital foramen (AIOF) to line A; E: vertical distance between IOF and AIOF; F: horizontal distance between IOF and AIOF; G: distance between the mid-superior edge of the AIOF and the mid-superior edge of the IOF; * $p<0.001$ (Mann-Whitney test was used to compare antimeres); ** $p<0.05$ (t-test of Student was used to compare antimeres); † Values were described as Median±interquartile range (IQR). The other linear measurements were described as Mean±SD.

Table 5. Mean or Median distance (mm) ± SD or IQR values of the sexual dimorphism analysis of the infraorbital foramen.

		IOF-A	IOF-B	IOF-C	HD	VD	A	B	C	D	E	F	G
p-value		**0.083**	**0.148**	**<0.001 ****	**0.108**	**0.053 †**	**<0.001 ****	**0.32**	**0.032 ****	**0.695**	**0.718**	**0.815**	**0.654**
Right	**Male N = 23**	7.23 (1.72)	15.06 (1.50)	29.63 (4.39)	2.99 (0.56)	3.64 (0.58) †	54.04 (3.0)	15.17 (2.4)	30.25 (2.9)	19.85 (0.9)	8.74 (4.0)	8.43 (4.6)	13.16 (5.5)
	Female N = 47	6.39 (1.94)	14.40 (1.90)	25.46 (3.99)	2.74 (0.64)	3.33 (0.90) †	50.46 (3.4)	14.41 (3.1)	28.81 (2.3)	20.50 (2.5)	7.76 (3.5)	7.69 (4.1)	11.39 (5.2)
p-value		0.016 * †	0.054	<0.001 **	0.011 **	0.106	<0.001 * †	0.054 †	<0.001 **	0.714	0.606 †	0.402	0.797 †
Left	**Male N = 23**	7.59 (1.70) †	15.71 (2.09)	29.2 (4.35)	3.46 (0.55)	3.58 (0.63)	55.09 (3.61) †	15.01 (2.94) †	31.31 (1.88)	19.23 (3.84)	5.59 (4.33) †	6.12 (3.09)	6.0 (6.35) †
	Female N = 47	6.47 (1.59) †	14.69 (2.01)	25.52 (3.82)	3.08 (0.58)	3.28 (0.75)	51.38 (4.67) †	13.29 (3.24) †	29.22 (2.57)	18.33 (4.57)	5.84 (4.41) †	7.79 (3.61)	7.91 (4.54) †
p-value		0.006 * †	0.02 **	<0.001 **	0.005 **	0.014 **	<0.01 * †	0.024 * †	<0.001 **	0.87	0.90	0.64	0.92
Total	**Male N= 46**	7.17 (1.85) †	15.39 (1.83)	29.42 (4.33)	3.23 (0.60)	3.64 (0.62)	54.67 (2.86) †	15.40 (3.06) †	30.79 (2.51)	19.46 (2.97)	6.76 (4.21)	6.99 (3.62)	10.12 (5.50)
	Female N = 94	6.43 (1.87) †	14.55 (1.95)	25.49 (3.88)	2.91 (0.63)	3.33 (0.74)	50.91 (4.64) †	13.69 (3.43) †	29.01 (2.44)	19.19 (3.94)	7.0 (4.04)	7.75 (3.67)	10.37 (5.34)

IOF-A: vertical distance from the center of the upper margin of the IOF to the infraorbital margin; IOF-B: from the center of the medial margin of the IOF to the lateral edge of the piriform aperture; IOF-C: vertical distance from the center of the lower margin of the IOF to the alveolar border; HD: horizontal diameter; VD: vertical diameter; A: distance between the most anterior point of the ANS to the lowest point of the ZS; B: Distance from the mid-upper edge of the IOF to line A; C: horizontal distance from ANS to the point of intersection of the IOF vertical line with line A; D: Vertical distance from the mid-superior edge of the accessory infraorbital foramen (AIOF) to line A; E: vertical distance between IOF and AIOF; F: horizontal distance between IOF and AIOF; G: distance between the mid-superior edge of the AIOF and the mid-superior edge of the IOF; * p<0.001 (Mann-Whitney test was used to compare antimeres); ** p<0.05 (t-test of Student was used to compare antimeres); † Values were described as Median±interquartile range (IQR). The other linear measurements were described as Mean±SD.

VD, A, B, and C were larger in males than in females (p<0.05).

Discussion

Due to the anatomical diversity and the inherent associations with neurovascular elements, the morphology and dimensions of the IOF, the existence of AIOF, and their spatial relations with other craniometric landmarks hold significant physiological and radiological relevance[7]. These features are crucial components in the craniofacial studies, providing essential landmarks that assist surgeons and dentists in precision interventions[8].

Shape and Direction of the IOF:

In terms of shape, the present study demonstrated that the majority of foramina on both left and right sides and both genders were oval or round, while a minority were triangular or semilunar. That was similar to a Hawaiian and Korean studies[9,10]. In another study, with a Lebanese population, the majority was oval on both sides[11]. Also, this study revealed that the direction of the foramen opening predominantly faces medially downwards (49% of the IOFs analyzed) and it was found mainly in men, since of the 46 foramina recorded, 28 (almost 61% of the foramina found in male skulls) opened in this way, while, in women, out of 94 foramina studied, 41 open in this way (accounting for almost 44% of the foramina analyzed in female skulls). These results were similar to an Indian and Hawaiian studies, who has also observed the medially directional pattern as the most frequent on both sides studied[9,10]. These findings could be important for physicians and dentists in Northeast Brazil, since the anatomy of IOF shows variability according to the ethnic population analyzed. The precise understanding of the morphology of this region could help the angulation of the needle insertion to avoid iatrogenic lesions, for example[10].

Accessory Infraorbital Foramen:

The analysis of the position and presence of the AIOF is also crucial because health professionals need to determine whether the neurovascular structures follow the path of the IOF to avoid painful or hemorrhagic complications during surgeries[12].

The present study indicated that, in Northeastern population of Brazil, for every 6 IOF studied, an AIOF was found, corresponding to 16% of the findings. These results were inferior to a Hawaiian and superior to Lebanese studies, which present respectively on average 35% and 8.6% of the skulls with AIOF[10,13]. This study also compared the frequency of AIOF according to gender. In males, it was found 34% AIOF and in female it was found 66%. These results were different from a Lebanese study, which present 76% of AIOF in male and 24% in female[13]. Differentiating by side, 39% of AIOF was present on the right side and 61% on the left side in the present study. The previously mentioned studies didn't find any differences in IOF distribution between the right and left sides.

Once again, it is noted that the ethnic formation of populations can influence their anatomy. Brazilian miscegenation even causes regional differences in the same country, as each region has a different ethnic origin. This has already been confirmed in other studies that analyzed the morphometry of other bone points of interest in the skull[14,15]. It is important to highlight that not only ethnic origin, but gender must also be considered by health professionals working with anesthetic blocks in Northeast Brazil. It appears that in this population there is a higher incidence of AIOF in women, showing the importance of ethnic, gender and even antimeria analysis for the procedures performed in this population evaluated in the present study.

To the best of our knowledge, only a Hawaiian study and our study investigated the location of the AIOF, with different results. While our study found the AIOF in a superomedial position to the IOF, the Hawaiian study found the superior location to be more prevalent in their population, despite also finding a reasonable amount of AIOF superiomedially to the IOF[10]. These findings are interesting as it is expected that the nerve components of the AIOF may be directed more towards the nasal and ocular regions. Therefore, it is necessary to be careful when carrying out aesthetic procedures near the base of the nose or the lower eyelid region, so as not to injure these branches originating from the AIOF.

IOF dimensions:

Information about the dimensions and symmetry of cranial foramina is crucial in the field of radiology, especially for identifying pathologies that can be diagnosed through computed tomography and magnetic resonance imaging[7,11,13,16]. Additionally, understanding the variations and anatomical characteristics of the IOF can help reduce the risk of injury and complications to the infraorbital neurovascular plexus during surgical or anesthetic procedures. Injury to this neurovascular plexus can lead to significant bleeding, numbness of the lower eyelid, upper lip, ala of the nose, as well as the upper incisors and canines[17,22].

The present study observed that the horizontal diameter (HD) was found to be larger on the left side than on the right side in the total sample, in males, and in females ($p<0.05$). An American study also showed that the left side is larger than the right[10]. Conversely, a Turkish and an Indian study indicated that the right side is larger than the left, with slightly larger measurements overall[23]. Moreover, studies from northeastern Brazil and South Korea demonstrated that the left side was larger in men than in women[24,25]. Not only HD, but also vertical diameter (VD) had larger values in males when the total sample was considered in the present study.

Other studies conducted in Brazil, South Korea, and Turkey also showed these differences[16,24,25]. Sexual dimorphism is a well-documented phenomenon in human skulls. In 1901, Pfitzner estimated that the head width in women was 4% smaller than that in men[26]. Classical findings like and the ethnic diversity among the studied populations may partially explain the larger distances observed in male skulls.

Thus, the present study demonstrated that the male IOF has larger dimensions than the female IOF, indicating that gender and side should be considered during ION anesthesia or procedures involving the maxillary region. This information on morphological variability can be useful for efficient nerve block and for minimizing the risk of iatrogenic injuries during surgical and aesthetic procedures.

Distance from IOF to neighboring structures:

In this study, the distance from the IOF to three neighboring structures was measured (to the inferior orbital margin, to the lateral border of the piriform aperture, and to the alveolar border). Knowledge of these distances is important for a more accurate estimation of the IOF location in clinical practice and efficient neural block in this region, resulting in greater benefit to the patient[4].

Several articles have described the IOF as being 6-8mm below to the inferior margin of the orbit[3,4,10,16,23,24]. The measurements found in the literature were similar to those obtained in this study (7.17mm in men and 6.43mm in women). Additionally, the mean distance from the IOF to the inferior orbital margin (IOF-A) showed that males have a greater distance than females in the total sample and also on the left side ($p<0.05$). An Indian study and a Pakistani study reported a greater distance on the right side[3,27]. No studies, to the best of our knowledge, have analyzed these differences between sexes.

The distance from the IOF to the lateral border of the piriform aperture (IOF-B) was found to be greater in males than in females, measuring an average of 15.39mm and 14.55mm, respectively ($p<0.05$). With very similar measurements, a Brazilian study also demonstrated that the left side is larger in men than in women[4]. Some studies reported measurements between 16mm and 18mm[10,23,27].

The distance from the IOF to the alveolar border (IOF-C) was found to be greater in males than in females in the total sample and on both sides ($p<0.05$) (Table 5). Only two Indian studies reported that the right side was larger than the left in the total skull sample[23,27]. No studies compared that distance between sexes as our study did. Interestingly, a Pakistani study has found very high values (over 40mm) for this measure, which were inconsistent with the majority of studies[3].

Detailed knowledge of the distance from the IOF to the alveolar border is important for professionals performing intraoral ION anesthesia. Since the needle is inserted through the mouth at the level of the incisor, along the margin of the alveolo-buccal mucosa, in the subsulcal plane, a lack of caution regarding depth when approaching the foramen can cause undesirable injuries to the ION or adjacent regions. A case of endophthalmitis following infraorbital nerve block via intraoral route, caused by an accidental injury to the eyeball, has been reported in the literature[28]. Therefore, considering that our study demonstrated that men have the IOF positioned, on average, 4mm higher in relation to the alveolar border than the IOF of women, on both sides, it is expected that this IOF in females will be closer to the alveolar border, indicating a higher attention from the professional when identifying the depth and level of anesthesia to be applied.

A practical application of this morphometric analysis concerns the location of the IOF, which can be estimated from palpation of the infraorbital rim, the lateral rim of the piriformis aperture, and the alveolar rim (Figure 4). First, the infraorbital rim should be palpated and followed downward for approximately 7mm for men and 6.5mm for women. Then, the rim of the piriformis aperture should be palpated and followed horizontally and laterally for approximately 15mm for men and 14.5mm for women (Figure 4A and 4C), or the alveolar rim should be palpated and followed upward for 29mm for men and 25.5mm for women (Figures 4B and 4D).

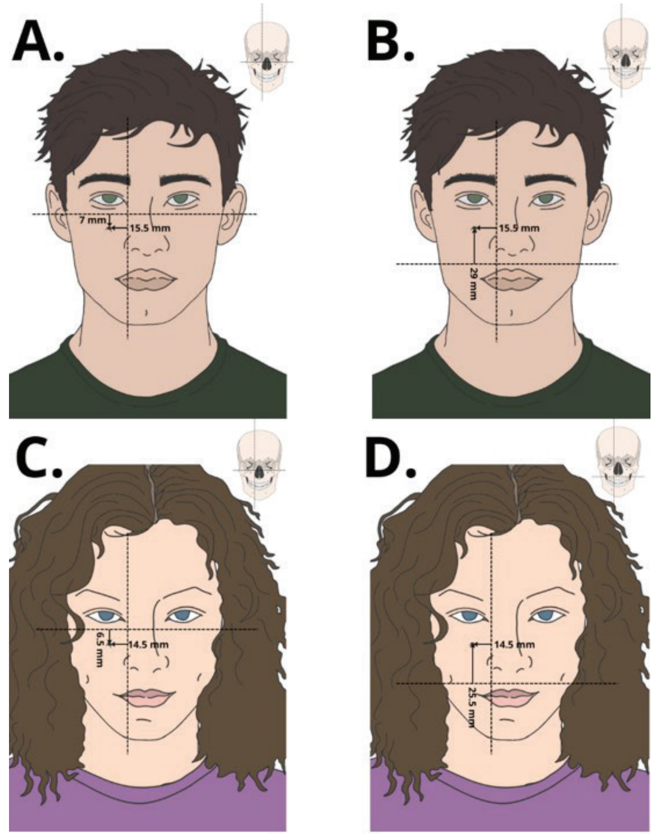

Figure 4. Illustration describing the predictive method for localizing the IOF in clinical practice.
Legend: (A) Measure 7 mm below the infraorbital rim and 15.5mm away from the edge of the piriformis aperture. (B) Measure 15.5mm away from the edge of the piriformis aperture and 29mm above the alveolar rim. (C) Measure 6.5 mm below the infraorbital rim and 14.5mm away from the edge of the piriformis aperture. (D) Measure 14.5mm away from the edge of the piriformis aperture and 25.5mm above the alveolar rim.

Craniometric distances:

Some studies measured the distance from the IOF to the anterior nasal spine, considering the inclination angle formed between the measured distance and the horizontal plane[3,4,9,29-31]. However, a Thai study developed a different method for estimating the IOF location without the need to calculate the mentioned angle of inclination[32]. This method involved drawing a line from the anterior nasal spine (ANS) to the lowest point of the zygomaticomaxillary suture (ZS), referred to as line A, and the vertical distance from the IOF to line A (B).

Our measurements compared to those in the Thai study showed significant differences. The distance from the ANS to ZS (A) was found to be higher in men in the total sample and on both sides, measuring an average of 54.67mm and 50.91mm for males and females, respectively ($p<0.05$). The Thai study also reported that men have a greater distance than women, but the measurements were relatively smaller than those found in our study (47.46mm and 45.9mm, respectively).

Interestingly, the horizontal distance from the ANS to the intersection point of the IOF vertical line with line A (measurement C) showed similar values to the findings of the Thai study for both males and females (approximately 30mm and 29mm, respectively), as well as the agreement that males have higher distances than females ($p<0.05$). The fact that measurement A is larger and measurement C is similar to the cited study means that the C ratio is 56% in our study, different from the 63% found in the Thai population. These percentages are important for locating the IOF in clinical practice.

The vertical distance from the IOF to line A (measurement B) showed higher values in males than in females, measuring 15.4mm and 13.69mm, respectively. The Thai study showed similar measurements for males but larger measurements for females (approximately 2mm higher)[32]. These findings are important for clinical practice since the IOF is located in a higher position in relation to the midface in Brazilian men than in Thai men, according to this prediction method. Therefore, it is evident that the measurements from the Thai study do not apply to the northeastern Brazilian population.

The distances E and F showed that the accessory infraorbital foramen (AIOF), when present, is on average 5.7mm above and 7.2mm horizontally distant from the

IOF on the left side, and 6.97mm above and 7.94mm horizontally distant on the right side. Few studies in the literature have measured the distance of the AIOF in relation to the IOF. Only one study conducted in an American population reported larger measurements for F (about 2mm difference), and another Thai study reported relatively smaller measurements (about 2mm difference for E and 1mm difference for F)[10,32]. It is concluded that the AIOF in the present study is less horizontally distant than the American population and is in a higher position (in addition to being further away horizontally) compared to the Thai population.

As already mentioned, nervous and vascular structures emerge from the AIOF and they innervate or vascularize regions of the face, mainly the external area of the nose[12]. These structures may or may not anastomose with structures leaving the IOF. In this sense, detailed anatomical knowledge of the relationship between these foramina must be taken into consideration in anesthesia or surgeries in this region, since the lack of knowledge of these relationships can lead to only partial anesthetic blocks, in addition to increasing the risk of iatrogenic injuries.

Another practical application of this morphometric analysis is demonstrated in Figure 5, which also could help locating the IOF. First, the anterior nasal spine (ANS) should be palpated at the top of the nasal philtrum, at the level of the patient's nostrils, and the lowest bony prominence of the cheek, which corresponds to the lowest point of the zygomatic-maxillary suture (ZS), and then a line should be drawn between the aforementioned points. Then, the midpoint of the line should be marked and continued upwards, approximately 15.5 mm in males or 13.5 mm in females (Figures 5A and 5C).

Limitations:

There were some limitations to this study worth noting. First, the study has an unequal sample of skulls by sex, with more female (47) than male (23), which may explain the smaller number of measurements that showed statistical relevance in male skulls, precisely because it has a larger sample. Second, few studies used the measures that were analyzed in this study, which makes comparisons between studies and extrapolation to clinical and surgical practice difficult. Therefore, more research is needed to compare these variations and certify these differences, since precise knowledge of the intricate anatomy of the infraorbital foramen is crucial for clinical and surgical interventions.

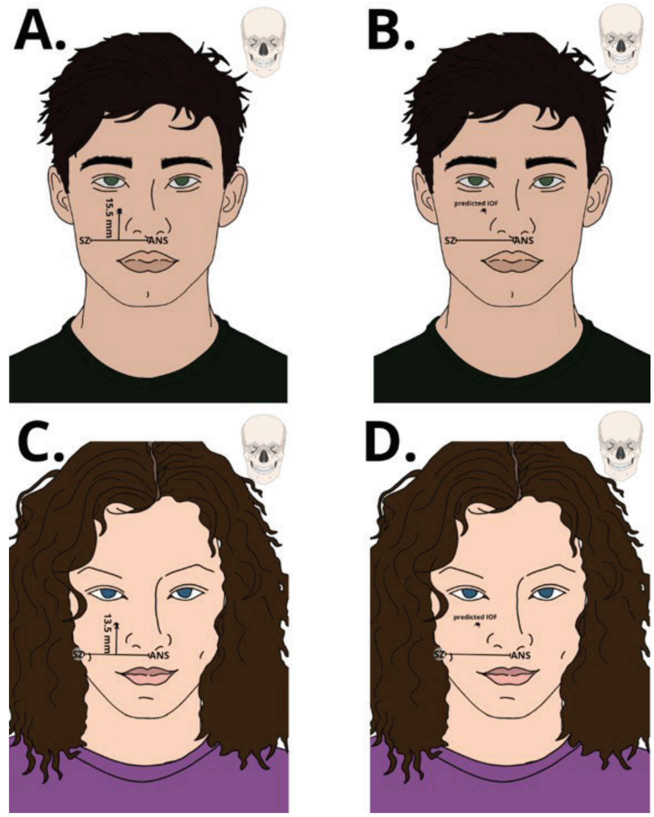

Figure 5. Illustration describing the predictive method for locating the IOF in clinical practice.
Legend: (A and C) Draw a line from the ANS to the SZ. Then, from the midpoint of the drawn horizontal line, go up approximately 15.5mm for men and 13.5mm for women. (B and D) Mark the location of the predicted IOF; ANS: anterior nasal spine; SZ: lowest point of the zygomatic-maxillary suture; IOF: infraorbital foramen.

Conclusion

This pioneering study analyzed the infraorbital foramen (IOF), its relationship with neighboring structures and the accessory infraorbital foramen (AIOF) in Paraíba, a state from Northeastern Brazil. The findings indicate a higher prevalence of oval and round shaped IOFs, with most openings directed medially downwards. AIOFs were present in 22% of skulls, predominantly on the left side and on a superomedial position related to the IOF. Craniometric analysis revealed that the most male measurements were larger than female measurements, while right and left sides showed no significant differences, except for the horizontal diameter (HD), which was larger on the left side than on the right. Understanding these anatomical characteristics can aid in accurately locating the IOF, thereby enhancing the precision of medical, dental, and aesthetic procedures.

References

1. Moore KL, Dalley AF, Agur AMR. Anatomia orientada para a clínica. 7th ed. Rio de janeiro: Koogan; 2014.
2. Tewari S, Gupta C, Palimar V, Kathur SG. Morphometric analysis of infraorbital foramen in south Indian dry skulls. Bangladesh J Med Sci. 2018;17(4):562-6.
3. Jafri SR, Muneeb A, Qureshi F, Sikander H, Arif A, Arshad A. Morphometric Analysis of Infraorbital Foramen in Human Dry Skulls. Pak J Med Health Sci. 2022 Oct 30;16(10):670-672.

4. Chrcanovic BR, Abreu MH, Custódio AL. A morphometric analysis of supraorbital and infraorbital foramina relative to surgical landmarks. Surg Radiol Anat. 2011 May;33(4):329-35.
5. Vanrell JP. Odontologia legal e antropologia forense. 2nd ed. Rio de janeiro: Guanabara Koogan; 2009.
6. Nanayakkara D, Peiris R, Mannapperuma N, Vadysinghe A. Morphometric Analysis of the Infraorbital Foramen: The Clinical Relevance. Anat Res Int. 2016;2016:7917343.
7. Smit S, Hutchinson EF, Kramer B. A morphometric analysis of the immature human infraorbital canal. Surg Radiol Anat. 2021 Feb;43(2):201-210.
8. Shin KJ, Shin HJ, Lee SH. Location of the infraorbital foramen with reference to soft tissue landmarks for regional nerve blocks during midface surgery. Clin Anat. 2020 Nov;33(8):1159-1163.
9. Mahajan A, Verma R, Razdan SK, Passey J. Morphological and Morphometric Relations of Infraorbital Foramen in North Indian Population. Cureus. 2023 Feb 1;15(2):e34525.
10. Polo CL, Abdelkarim AZ, von Arx T, Lozanoff S. The Morphology of the Infraorbital Nerve and Foramen in the Presence of an Accessory Infraorbital Foramen. J Craniofac Surg. 2019 Jan;30(1):244-253.
11. Cutright B, Quillopa N, Schubert W. An anthropometric analysis of the key foramina for maxillofacial surgery. J Oral Maxillofac Surg. 2003 Mar;61(3):354-7.
12. Iwanaga J, Kikuta S, Kusukawa J, Tomaszewski KA, Walocha JA, Tubbs RS. Anatomic Study of Accessory Infraorbital Nerves and Foramina: Application for a Better Understanding of Complications of Le Fort Fractures and Osteotomy. J Oral Maxillofac Surg. 2020 May;78(5):717-723.
13. Sokhn S, Challita R, Challita A, Challita R. The Infraorbital Foramen in a Sample of the Lebanese Population: A Radiographic Study. Cureus. 2019 Dec 14;11(12):e6381.
14. Sugano GT, Pauris CC, Silva YBE, Pandini FE, Palermo RBS, Buchaim DV, Buchaim RL, Chacon EL, Aparecida de Castro C, Pagani BT, Cunha MRD. Topographic and Morphometric Study of the Foramen Spinosum of the Skull and Its Clinical Correlation. Medicina (Kaunas). 2022 Nov 28;58(12):1740.
15. Ramalho Rodrigues R, Neto DFDN, Andrade Fernandes JV, Barreto LO, Barros Maciel do Amaral V, Karoline de Araújo Deca D, Freire de Albuquerque Figueiredo VL, Dantas de Lucena J, Bezerra da Silva I, Sales THA, Oliveira ASB. Morphological analysis of the jugular foramen in dry human skulls in northeastern Brazil. Anat Cell Biol. 2024 Jun 30;57(2):213-220.
16. Bahşi I, Orhan M, Kervancıoğlu P, Yalçın ED. Morphometric evaluation and surgical implications of the infraorbital groove, canal and foramen on cone-beam computed tomography and a review of literature. Folia Morphol (Warsz). 2019;78(2):331-343.
17. Ashwini LS, Mohandas Rao KG, Saran S, Somayaji SN. Morphological and morphometric analysis of supraorbital foramen and supraorbital notch: a study on dry human skulls. Oman Med J. 2012 Mar;27(2):129-33.
18. Caldeira JVC, Godas AGL, Carvalho GBA, Silva KRT, Machado ARSR, Almeida PF, Silva AV. Measurement of the jugular foramen in dry skulls from the Midwest region of Brazil. Braz J Health Rev. 2020;3(5):14614-14628.
19. Gour KK, Nair S, Trivedi GN, Gupta SD. Anthropometric measurements of infraorbital foramen in dried human skulls. Int J Biol Med Res. 2012;3(3):2003-6.
20. Kazkayasi M, Ergin A, Ersoy M, Tekdemir I, Elhan A. Microscopic anatomy of the infraorbital canal, nerve, and foramen. Otolaryngol Head Neck Surg. 2003 Dec;129(6):692-7.
21. Zarringhalam P, Parbhoo A, Von Arx D. Accessory infra-orbital nerves - an important anatomical lesson. Br J Oral Maxillofac Surg. 2014;52(8):e118-9.
22. Joseph CC, Soman MA, Jacob M, Nallathamby R. Morphometric variations in infra orbital foramen of dry adult human south Indian skulls with its surgical and anaesthetic significance. Int J Health Sci Res. 2015;5:130-4.
23. Tewari S, Gupta C, Palimar V, Kathur SG. Morphometric analysis of infraorbital foramen in south Indian dry skulls. Bangladesh J Med Sci. 2018 Oct 1;17(4):562-6.
24. Cisneiros de Oliveira LC, Silveira MP, de Almeida Júnior E, Reis FP, Aragão JA. Morphometric study on the infraorbital foramen in relation to sex and side of the cranium in northeastern Brazil. Anat Cell Biol. 2016 Mar;49(1):73-7.
25. Hong JH, Kim HJ, Hong JH, Park KB. Study of Infraorbital Foramen Using 3-Dimensional Facial Bone Computed Tomography Scans. Pain Physician. 2022 Jan;25(1):E127-E132.
26. Brooks S. The human skeleton in forensic medicine. By W.M. Krogman and M. Y. Iscan. Springfield: Charles C. Thomas. Am J Phys Anthropol. 1987;74:136-137.
27. Varshney R, Sharma N. Infraorbital foramen - Morphometric study and clinical application in adult Indian skulls. Saudi J Health Sci. 2013;2(3):151-155.
28. Weinand FS, Pavlovic S, Dick B. Endophthalmitis nach enoraler Blockade des Nervus infraorbitalis. Klin Monatsbl Augenh. 1997 Jun 25;210(6):402-404.
29. Zhang KR, Blandford AD, Hwang CJ, Perry JD. Anatomic Variations of the Infraorbital Foramen in Caucasian Versus African American Skulls. Ophthalmic Plast Reconstr Surg. 2019 Jan/Feb;35(1):25-28.
30. Nanayakkara D, Peiris R, Mannapperuma N, Vadysinghe A. Morphometric Analysis of the Infraorbital Foramen: The Clinical Relevance. Anat Res Int. 2016;2016:7917343.
31. Preza A d'Oliveira G. Determinação do gênero em ossadas, usando a fossa rombóide da clavícula. Dissertação (Mestrado) – Universidade Estadual de Campinas, Faculdade de Odontologia de Piracicaba. Piracicaba, SP, 2003.
32. Suntiruamjairucksa J, Chentanez V. Localization of infraorbital foramen and accessory infraorbital foramen with reference to facial bony landmarks: predictive method and its accuracy. Anat Cell Biol. 2022 Mar 31;55(1):55-62.

Mini Curriculum and Author's Contribution

1. João Paulo de Oliveira Jerônimo Rodrigues: data acquisition, discussion of the results and writing of the manuscript.

2. Alexandre Casusão de Sousa: data acquisition, discussion of the results and writing of the manuscript.

3. João Vitor Andrade Fernandes: data acquisition, discussion of the results and writing of the manuscript.

4. Lucas Brito Meira: data acquisition, discussion of the results and writing of the manuscript.

5. Emmily Neves de Araújo Pereira: data acquisition, discussion of the results and writing of the manuscript.

6. Reynaldo de França Souza: data acquisition, discussion of the results and writing of the manuscript.

7. Jalles Dantas de Lucena: review of the manuscript.

8. André de Sá Braga Oliveira: discussion of the results and writing of the manuscript, conception, and design of the study.

Received: August 1, 2025
Accepted: September 30, 2025

Corresponding author
Jalles Dantas de Lucena
E-mail: jallesdantas@gmail.com