

# Incidence and Morphological Characteristics of Accessory Infraorbital Foramina: An Analysis of Computed Tomography Scans

## Incidencia y Características Morfológicas del Foramen Infraorbitario Accesorio: Un Análisis de Tomografías Computarizadas

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**SUMMARY:** The accessory infraorbital foramen (AIOF) represents an anatomical bony skull variation. Its importance is reflected in the fact that branches of the infraorbital nerve can pass through it and can be exposed to injuries during anesthesia and surgical interventions. This study aims to determine the incidence and morphometric characteristics of the AIOF and to predict its position in relation to surrounding bony structures. The retrospective study analyzed 595 computed tomography (CT) scans (245 males and 350 females). Measurements of all parameters (dimensions and positions of the foramina) were performed using PACS tools on coronal sections in uncompressed DICOM image format. The incidence of the AIOF was 8.24 % (found on 49 skulls). Of these, 34 (69.39 %) had a unilateral AIOF, while 15 (30.61 %) had it bilaterally. The average vertical diameter (VD) was 2.70 mm, and the horizontal diameter (HD) was 2.62 mm. No statistically significant difference was found between the foramina on the left and right sides. The horizontal diameter of the AIOF was significantly larger in men than in women. The mean surface area was 4.28 mm<sup>2</sup>. In women, the foramen was statistically closer to the anterior nasal spine ( $p=0.01$ ), to the nasomaxillary suture ( $p=0.001$ ), and to the lower edge of the maxilla ( $p=0.03$ ). The most extensive percentage of foramina (97 %) were located superomedially to the infraorbital foramen, and only two (3 %) were positioned inferomedially. Position prediction can contribute to a better understanding of anatomical variations the infraorbital region and a more precise localization of AIOF.

**KEY WORDS:** Accessory infraorbital foramen; Computed tomography; Morphometric analysis; Clinical significance.

## INTRODUCTION

Accessory infraorbital foramen (AIOF) is a bony anatomical variation, that can be found near the infraorbital foramen (IOF) on the anterior surface of the maxilla. The infraorbital nerve and the infraorbital artery exit the cranial cavity through the IOF (Thunyacharoen *et al.*, 2022). The infraorbital artery supplies the lower eyelid, the subcutaneous facial muscles, the skin of the cheeks and nose, the upper incisors and canines, and the mucosa of the maxillary sinus (Désiré *et al.*, 2023). The infraorbital nerve provides sensory innervation to a relatively large face area and has a close topographic relationship with the eye, nasal, and oral cavity structures (Açikgöz, 2021). If the AIOF is present, some of the branches of the infraorbital nerve may pass through it, most often for innervation of the lower eyelid and outer side of the nose. Infiltration of anesthetics into the infraorbital

nerve is performed during oral and maxillofacial surgical procedures, in plastic and reconstructive surgery, nasal surgery, and specific dermatological procedures when it is necessary to achieve anesthesia of the central part of the face (Thunyacharoen *et al.*, 2022; Désiré *et al.*, 2023). An infraorbital nerve block is a well-known regional anesthesia technique that can provide intraoperative and postoperative pain relief during endoscopic interventions of the nasal cavity (Polo *et al.*, 2019; Shin *et al.*, 2020). To prevent complications during these procedures, detailed knowledge of the anatomy of the maxilla, the dimensions, and the localization and the possible existence of an AIOF is required. An insufficient degree of anesthesia of the infraorbital nerve may be achieved if one of its branches passes through the AIOF and not through the IOF (Thilakumara *et al.*, 2021).

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Literature data agree that one AIOF is most often present, located superomedial to the IOF in approximately 90 % of cases (Hwang *et al.*, 2004; Tezer *et al.*, 2011; Kazkayasi *et al.*, 2001; Kadanoff *et al.*, 1970; Berry 1995) (Fig. 1A & 1B). It is more often present on the right half of the face (Polo *et al.*, 2019; Rai *et al.*, 2013), but some studies have shown that it can also be located on the left (Bressan *et al.*, 2004; Hwang *et al.*, 2004; Tezer *et al.*, 2011). In a smaller number of examined skulls, the presence of AIOF on both sides was published (Shin *et al.*, 2020). Little data indicate possible differences in the prevalence of AIOF based on the subject's sex, and to our knowledge, only Thilakumara *et al.* (2021), examined this association and reported that it was not statistically different (Thilakumara *et al.*, 2021).

Studies have mainly focused on investigating the morphological properties of the AIOF. Very few have examined its size, content, and precise localization to the surrounding bony or soft tissue structures. According to the reviewed literature, no study has been conducted in our country to determine the incidence of AIOF in the Serbian population. Due to the aforementioned clinical importance of AIOF and the heterogeneity observed in the literature regarding morphometric findings, the idea for this research arose.

Our study aimed to determine the incidence of AIOF in the Serbian population. By analyzing computed tomography images, we calculated the dimensions of the AIOF and their distance from surrounding bony structures and performed a prediction of their position.

## MATERIAL AND METHOD

The research was conducted at the Center for Radiology, University Clinical Center of Vojvodina in Novi Sad and approved by the Ethics Committee of the Clinical Center of Vojvodina (decision No. 00-223). The study included images of patients who underwent head computed tomography (CT) imaging (General Electric Revolution 128) for various indications. The images were retrospectively analyzed from December 2019 to December 2022, from the medical image archiving system (PACS, Picture Archiving and Communication System, Vue PACS v 12.1.6.1005).

Parameter measurements were performed using PACS system tools on coronal sections in uncompressed DICOM (Digital Imaging and Communications in Medicine) image format. The slice thickness of the imaged region of interest was 1 mm and 5 mm, and bone reconstructions of the images were performed on slices of 0.63 mm and 1 mm. A total of 595 CT scans of the skull were examined (245 female and 350 male subjects), and the average age of the subjects was 55 years.

We excluded patients with congenital facial deformities, previous fractures, and surgical procedures in the maxilla, frontal bone, and mandible and patients younger than 18 years. With the 3D reconstruction, skull images with the AIOF were determined (49), i.e., a total of 98 sides of the skull (right and left together) were selected and further analyzed. The number of AIOF was determined by inspection, as well as their position (superomedial (SM),

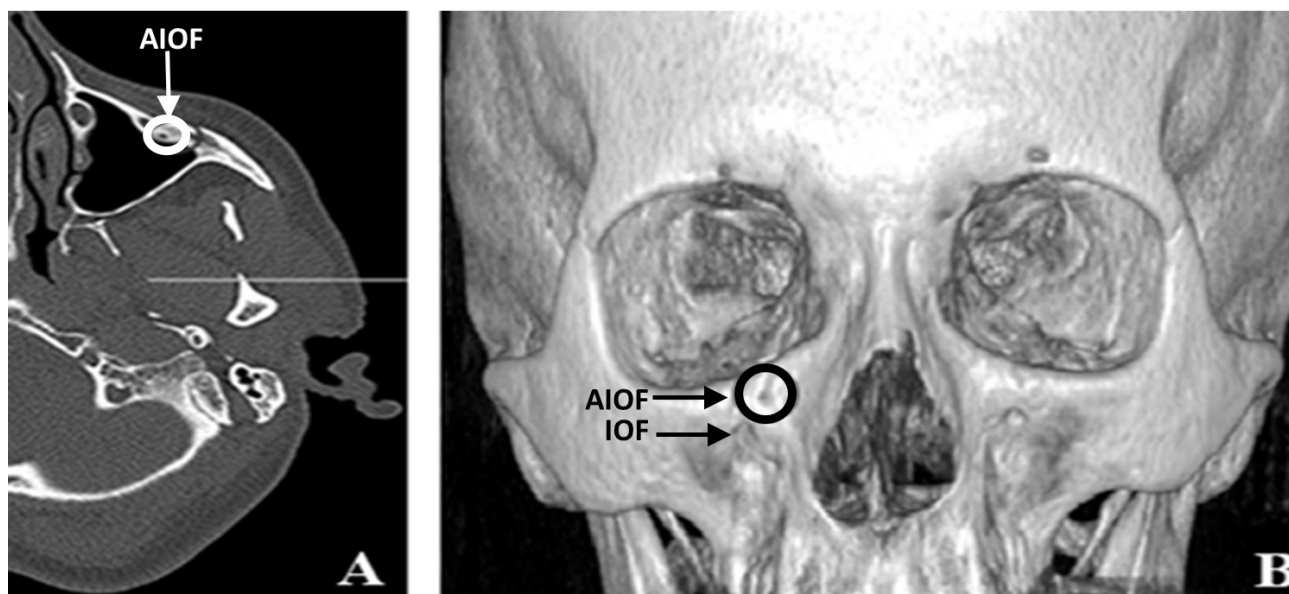


Fig. 1. AIOF marked with a white circle on the transverse CT scan of the head (A). 3D view of the skull showing the AIOF (marked with a black circle) and IOF indicated with black arrow (B).

inferomedial (IM), superolateral (SL), or inferolateral (IL)) concerning the IOF (Fig. 2).

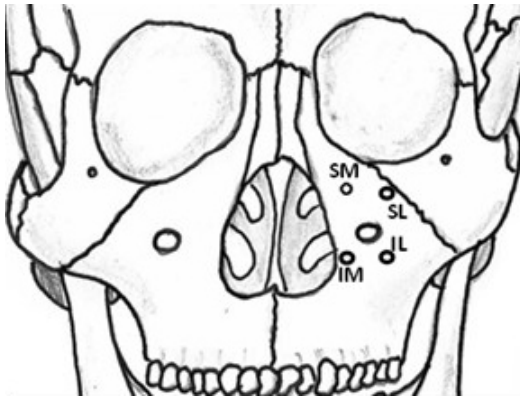


Fig. 2. Schematic representation of the position of AIOF in relation to IOF (SM-superomedial; IM-inferomedial; SL-superolateral; IL-inferlateral).

Measurement and calculation of AIOF dimensions included the following parameters (Fig. 3):

- HD: horizontal diameter of AIOF, the distance between the inner (medial) and outer (lateral) edges of the AIOF, measured along a horizontal line.
- VD: vertical diameter of AIOF, represents the distance between its upper and lower edges, measured along a vertical line.
- S: surface area of AIOF.

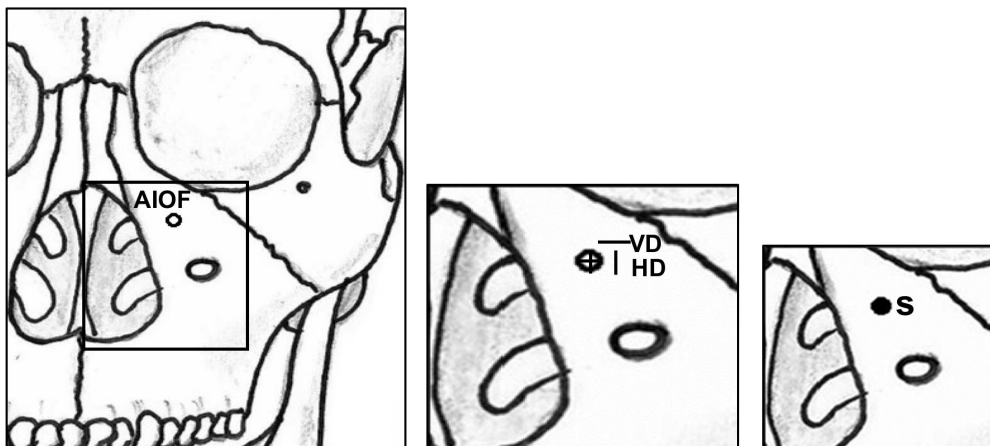


Fig. 3. Schematic representation of the dimensional parameters of AIOF on the human skull (HD-horizontal diameter; VD-vertical diameter; S-surface area).

Measurement and calculation of parameters describing the position of AIOF to the surrounding anatomical structures (Fig. 4A):

- AIOF-IOF: distance from the center of AIOF to the most proximal point of IOF.
- AIOF-IOM: distance from the center of AIOF to the most prominent point of the infraorbital margin.
- AIOF-MFL: distance from the center of AIOF to the medial face line.
- AIOF-ANS: distance from the center of AIOF to the most prominent point of the anterior nasal spine.
- AIOF-NMS: distance from the center of AIOF to the most distal point of the nasomaxillary suture.
- AIOF-MAP: distance from the center of AIOF to the lower edge of the maxillary alveolar process.

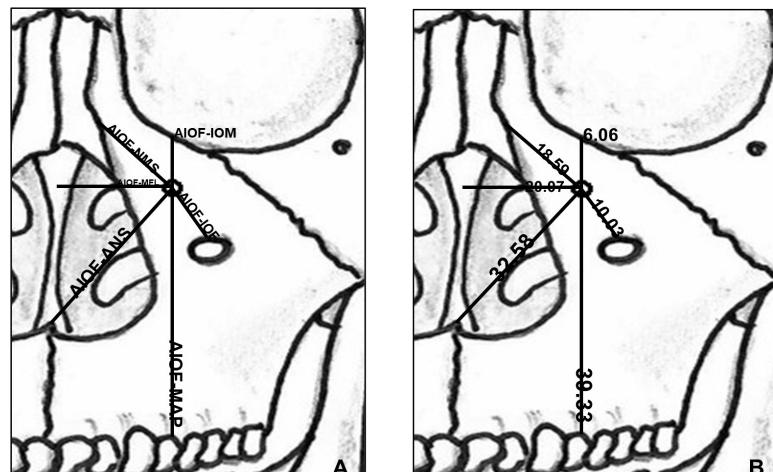


Fig. 4. Schematic representation of the AIOF position (A) in relation to: IOM (infraorbital margin); NMS (nasomaxillary suture); ANS (anterior nasal spine); MAP (maxillary alveolar process); and IOF (infraorbital foramen). Position prediction of AIOF (B, distances are in millimeters).

The obtained data were analyzed in the GraphPad 6 Prism Software 10.0.0 program. The results are presented as descriptive statistics parameters (mean value ( $\bar{X}$ ), standard deviation (SD), and minimum and maximum value (Min-Max)). Student's t-test was used to determine the difference between groups. A statistically significant difference was considered if  $p < 0.05$ . The obtained results were presented in the form of images and tables.

## RESULTS

AIOF was observed in 49 out of 595 analyzed CT skull scans, corresponding to an incidence of 8.24%. Among the skulls with AIOF, the foramen appeared unilaterally in 34 cases (69.39 %) and bilaterally in 15 cases (30.61 %) (Fig. 5). Altogether, 64 foramina were identified and morphometrically analyzed. Among the unilateral occurrences, a symmetrical distribution was found (17 on both sides).

Table I represents the distribution of AIOFs by sex; 18 of the 34 skulls with unilateral foramen belonged to males (52.94 %), while 16 belonged to females (47.06 %). The bilateral presence of AIOF was almost equally represented in both sexes (Table I).

Table I. Distribution of unilateral and bilateral AIOFs in relation to sex (N=49).

|        | Unilateral (N=34) | Bilateral (N=15) |
|--------|-------------------|------------------|
| Male   | 18 (52.94 %)      | 8 (53.33 %)      |
| Female | 16 (47.06 %)      | 7 (46.67 %)      |

Regarding morphometric characteristics, the AIOF had a VD of 2.70 mm and a horizontal HD of 2.62 mm. The mean distance from the infraorbital foramen (IOF) was 10.03 mm, while the average distance from the MFL was 20.70 mm. The average surface area of all examined AIOFs was 4.28 mm<sup>2</sup> (Table II).

Table II. Distribution of unilateral and bilateral AIOFs in relation to sex (N=49).

| Parameters           | Mean±SD    | Min-Max     |
|----------------------|------------|-------------|
| VD (mm)              | 2.70±1.22  | 1.00-6.00   |
| HD (mm)              | 2.62±1.53  | 1.00-7.00   |
| S (mm <sup>2</sup> ) | 4.28±3.39  | 0.80-20.00  |
| AIOF-IOF (mm)        | 10.03±2.72 | 5.00-17.00  |
| AIOF-IOM (mm)        | 6.06±2.95  | 1.00-17.00  |
| AIOF-MFL (mm)        | 20.70±2.85 | 13.00-27.00 |
| AIOF-ANS (mm)        | 32.58±3.37 | 25.00-41.00 |
| AIOF-NMS (mm)        | 18.69±3.12 | 13.00-26.00 |
| AIOF-MAP (mm)        | 39.33±4.31 | 30.00-49.00 |

Although slight differences regarding morphometric values were noted between the left and right sides, none reached statistical significance. The most notable variation was the HD, being greater on the left side (2.89 mm) than on the right (2.37 mm). The AIOF on the right side was positioned closer to the MFL than the one on the left (20.29 mm vs. 21.29 mm) (Table III).

When considering sex differences (Table IV), the HD was significantly greater in males (3.03 mm) compared to females (2.15 mm). In female subjects, the AIOF was significantly closer to the ANS, NMS, and MAP. Although not statistically significant, male subjects also tended to have a larger AIOF area (Table IV).

Regarding position relative to the IOF, most AIOFs (97 %) were located superomedially, with only a small number (3 %) found inferomedially. No foramina were located lateral to the infraorbital foramen in the studied sample. A prediction of the position of AIOF was performed based on the results of our study and depicted in Fig. 4B.

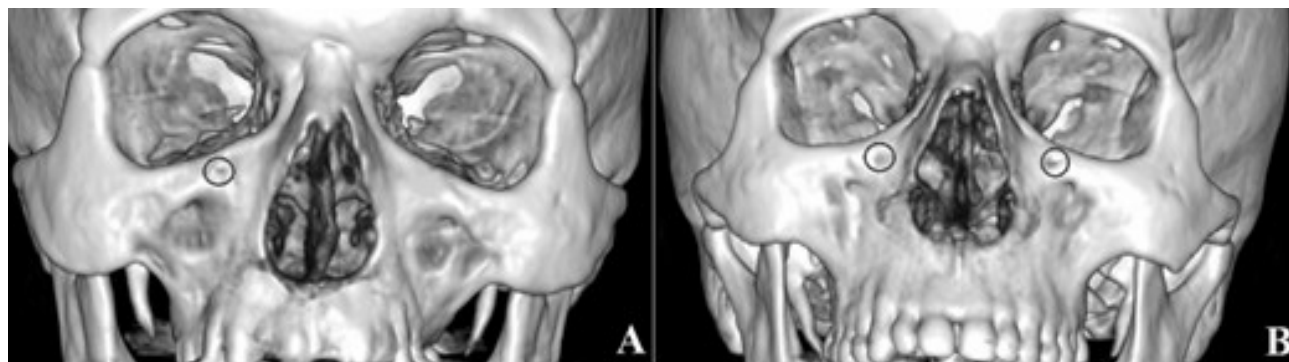


Fig. 5. CT scans illustrating the presence of AIOF on the anterior aspect of the skull. Unilateral AIOF on the right side (A), and bilateral (B). AIOFs are marked with a black circle.

Table III. Descriptive statistics parameters and differences in dimensions and position of AIOFs (N=64) in relation to the side of the skull.

| Parameters           | Left side (N=32) |             | Right side (N=32) |             | P-value |
|----------------------|------------------|-------------|-------------------|-------------|---------|
|                      | Mean $\pm$ SD    | Min-Max     | Mean $\pm$ SD     | Min-Max     |         |
| VD (mm)              | 2.90 $\pm$ 1.27  | 1.00-6.00   | 2.53 $\pm$ 1.16   | 1.00-6.00   | 0.23    |
| HD (mm)              | 2.89 $\pm$ 1.68  | 1.00-7.00   | 2.37 $\pm$ 1.36   | 1.00-6.00   | 0.19    |
| S (mm <sup>2</sup> ) | 4.68 $\pm$ 3.03  | 1.20-15.00  | 3.94 $\pm$ 3.75   | 0.80-20.00  | 0.39    |
| AIOF-IOF (mm)        | 10.13 $\pm$ 2.75 | 6.00-17.00  | 9.97 $\pm$ 2.75   | 5.00-17.00  | 0.82    |
| AIOF-IOM (mm)        | 6.23 $\pm$ 3.07  | 1.00-17.00  | 5.84 $\pm$ 2.90   | 1.00-17.00  | 0.61    |
| AIOF-MFL (mm)        | 21.29 $\pm$ 2.87 | 13.00-27.00 | 20.29 $\pm$ 2.78  | 15.00-25.00 | 0.15    |
| AIOF-ANS (mm)        | 32.87 $\pm$ 3.01 | 28.00-41.00 | 32.44 $\pm$ 3.69  | 25.00-40.00 | 0.61    |
| AIOF-NMS (mm)        | 18.64 $\pm$ 2.82 | 13.00-24.00 | 18.87 $\pm$ 3.36  | 14.00-26.00 | 0.77    |
| AIOF-MAP (mm)        | 38.68 $\pm$ 4.39 | 30.00-47.00 | 39.94 $\pm$ 4.265 | 33.00-49.00 | 0.25    |

Table IV. Descriptive statistics parameters and differences in dimensions and position of the AIOFs (N=64) in relation to sex.

| Parameters           | Male (N=34)      |             | Female (N=30)    |             | P-value |
|----------------------|------------------|-------------|------------------|-------------|---------|
|                      | Mean $\pm$ SD    | Min-Max     | Mean $\pm$ SD    | Min-Max     |         |
| VD (mm)              | 2.97 $\pm$ 1.40  | 1.00-6.00   | 2.40 $\pm$ 0.89  | 1.00-4.00   | 0.06    |
| HD (mm)              | 3.03 $\pm$ 1.66  | 1.00-7.00   | 2.15 $\pm$ 1.23  | 1.00-5.00   | 0.02*   |
| S (mm <sup>2</sup> ) | 5.02 $\pm$ 4.09  | 1.00-20.00  | 3.45 $\pm$ 2.12  | 0.80-9.00   | 0.06    |
| AIOF-IOF (mm)        | 10.20 $\pm$ 2.60 | 6.00-17.00  | 9.83 $\pm$ 2.87  | 5.00-17.00  | 0.59    |
| AIOF-IOM (mm)        | 6.26 $\pm$ 3.77  | 1.00-17.00  | 5.83 $\pm$ 1.64  | 1.00-9.00   | 0.56    |
| AIOF-MFL (mm)        | 20.76 $\pm$ 3.00 | 13.00-27.00 | 20.63 $\pm$ 2.71 | 15.00-25.00 | 0.86    |
| AIOF-ANS (mm)        | 33.65 $\pm$ 3.37 | 25.00-41.00 | 31.37 $\pm$ 2.99 | 26.00-40.00 | 0.01*   |
| AIOF-NMS (mm)        | 19.88 $\pm$ 2.91 | 15.00-26.00 | 17.33 $\pm$ 2.81 | 13.00-23.00 | 0.01*   |
| AIOF-MAP (mm)        | 40.44 $\pm$ 4.51 | 31.00-49.00 | 38.07 $\pm$ 3.75 | 30.00-48.00 | 0.03*   |

## DISCUSSION

The incidence of AIOF differs according to the geographical area of the studied population and varies widely, from 4.7 % in Italy (Bressan *et al.*, 2004) to 56.6 % in Turkey (Dagistan *et al.*, 2017). In our study, the frequency of AIOF was 8.24 %, while the highest reported frequency (47.6 %) was found by Polo *et al.* (2019). Other studies have shown a lower percentage of AIOF, more consistent with our results (Hwang *et al.*, 2004, An *et al.*, 2023). Besides the anthropological differences between the examined skulls, Hwang (2015) explained a correlation between the latitude of the area where the skulls were analyzed and the AIOF prevalence. He found that the incidence of AIOF is higher in colder climates (Arctic, 30.2 %) compared to warmer ones (Africa, 13.4 %), citing the exposure of the midface to cold as the cause. The high incidence of AIOF in some studies may be related to the sensitivity of the study's method. Research that analyzed images taken on a CBCT (Cone Beam Computed Tomography) scanner classified even the smallest visible opening in the bone as supernumerary foramen (even those less than 1 mm) (Dagistan *et al.*, 2017; An *et al.*, 2023). In contrast, on conventional CT machines, such small changes are difficult to classify, clearly visualize, and measure.

Our study's results show that most openings (69.39 %) were present only on one side of the skull, while in 30.61 %, AIOF was seen bilaterally. This is consistent with other studies that have also shown that a single supernumerary infraorbital foramen is most commonly present (Dagistan *et al.*, 2017; Suntirumjairucksa & Chentanez, 2022; Nam *et al.*, 2017), with a higher frequency on the left side (Martins-Júnior *et al.*, 2017; Polo *et al.*, 2019; An *et al.*, 2023). The frequency of bilateral AIOFs on skulls ranges from 9.1 % to 25 % in different studies (Polo *et al.*, 2019; Shin *et al.*, 2020; Ali *et al.*, 2017). Our study found an equal prevalence of AIOFs on both sides, which agrees with the results from Turkey (Dagistan *et al.*, 2017). However, in the research from Brazil, the prevalence is higher on the right side (52.08%) compared to the left (47.92 %) (Martins-Júnior *et al.*, 2017).

Only a few studies have measured the dimensions of the AIOF, while to our knowledge, this is the only study that also calculated the area of the AIOF. All the foramina examined in our study had approximately equal HD (2.62 mm) and VD (2.70 mm), indicating their circular shape. These two parameters are not significantly different between

the sides. Polo *et al.* (2019), reported that the VD of the right AIOFs (1.23 mm) was statistically significantly larger compared to the same diameter of the left AIOFs (0.94 mm). The average value of the AIOF area in the entire sample of this study is 4.28 mm<sup>2</sup>, and a comparison by sex shows that it is larger in men (5.02 mm<sup>2</sup>) than in women (3.45 mm<sup>2</sup>). In addition, our results show that the HD of AIOF in men is significantly larger than in women (3.03 mm vs 2.15 mm,  $p = 0.02$ ). The higher values of the parameters that show the size of AIOF in men confirm the constitutional differences between sexes.

The topographic relationship of AIOF and IOF is very important because the position of IOF is often taken as a target point when performing anesthesia and used as a reference point, without considering the possible existence of supernumerary openings nearby. Anthropological studies have examined the distance of the IOF from surrounding bony structures, but AIOF data mainly refer only to its incidence, not to morphometry. We found that the AIOF is 10.03 mm away from the IOF, i.e. 10.13 mm on the left side and 9.97 mm on the right. We also measured the distances of the AIOF from adjacent bony structures to predict its precise location (Fig. 4B). Those parameters do not differ when comparing their values regarding the side of the skull. Sex differences were found, and some were statistically significant: in women, AIOF is closer to the ANS ( $p = 0.01$ ), to the NMS ( $p = 0.01$ ), and the MAP ( $p = 0.03$ ). The reason for this is most likely the fact that male skulls are on average, 7.3% larger than female skulls, i.e., women have fewer facial bones, and the skull is shorter overall in all directions (Jones & Hill, 1993).

The rich vascularization and innervation of the midface make infraorbital region particularly susceptible to iatrogenic injuries (Uzun *et al.*, 2016). Branching of neural structures most likely affects the formation of the AIOF during the growth and development (Cutright *et al.*, 2003). Given that it is easily palpable through soft tissues, the IOM is often taken as a reference point in predicting the position of the IOF. For this reason, we measured the distance of the AIOF from the IOM and found that it was greater in men (6.26 mm) compared to women (5.83 mm), which is in agreement with the results of other studies (Rai *et al.*, 2013, Tezer *et al.*, 2011, Thilakumara *et al.*, 2021), indicating more caution when performing percutaneous access to the infraorbital nerve. The AIOF is 32.58 mm away from ANS in our study. Presentation of ANS on the face is on the most proximal point of the philtrum, and it is available for palpation in daily clinical practice. This location corresponds to the anthropological nasospinale point, which is projected as the lowest point of the nasal aperture, at the intersection of the midsagittal plane and the horizontal line passing

between the nose wings (Chu *et al.*, 2020). When considering the position of AIOF to IOF, our results are similar to the results of other studies (Hwang *et al.*, 2004; Tezer *et al.*, 2011; Suntirumjairucksa & Chentanez, 2022), indicating that in our country, the most frequent (97 %) is the superomedial position of AIOF. Anatomical knowledge of AIOF is necessary for surgeons performing Le Fort osteotomy, ablation, or blockade of the infraorbital nerve. This anatomical variation should be considered when sensory deficits in the upper lip or cheek area are diagnosed after such procedures. Given that it is not always feasible and applicable to perform CT or other imaging before performing surgical interventions in the facial area, it is very important to define palpable reference points, which would serve as guides when determining the position of the targeted openings or neural structures. Precise definition of the localization and morphology of the AIOF is not entirely consistent in different sources of literature; we believe that further studies are needed to more precisely assess the anatomical characteristics of variable openings on the skull, and especially to describe their positions on the soft tissue structures of the face.

## CONCLUSION

Based on the results obtained, this study has provided data regarding the prevalence, size, and position prediction of the AIOF of the human skulls. With a frequency of 8.24 %, this anatomical variation is most often present unilaterally. The AIOF is located superomedial to the IOF, approximately 10 mm from the IOF and 21 mm from the MFL. These findings open up new possibilities for defining reference points on the face that would serve as guides during the procedure of needle placement and anesthetic application, thus minimizing the chances of complications.

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**RESUMEN:** El foramen infraorbitario accesorio (FIOA) representa una variación ósea anatómica del cráneo. Su importancia se refleja en el hecho de que los ramos del nervio infraorbitario pueden atravesarlo y estar expuestos a lesiones durante la anestesia y las intervenciones quirúrgicas. Este estudio tuvo como objetivo determinar la incidencia y las características morfométricas del FIOA y predecir su posición en relación con las estructuras óseas circundantes. El estudio retrospectivo analizó 595 tomografías computarizadas (TC) (245 hombres y 350 mujeres). Las mediciones de todos los parámetros (dimensiones y posiciones de los forámenes) se realizaron utilizando herramientas PACS en secciones coronales en formato de imagen DICOM sin comprimir. La incidencia del FIOA fue del 8,24 % (encontrado en 49 cráneos). De éstos, 34 (69,39 %) tenían un FIOA unilateral, mientras que 15

(30,61 %) lo tenían bilateralmente. El diámetro vertical promedio (VD) fue de 2,70 mm y el diámetro horizontal (HD) fue de 2,62 mm. No se encontró diferencia estadísticamente significativa entre los forámenes del lado izquierdo y derecho. El diámetro horizontal del FIOA fue significativamente mayor en hombres que en mujeres. El área superficial media fue de 4,28 mm<sup>2</sup>. En las mujeres, el foramen estaba estadísticamente más cerca de la espina nasal anterior ( $p = 0,01$ ), de la sutura nasomaxilar ( $p = 0,001$ ) y del margen inferior del maxilar ( $p = 0,03$ ). El porcentaje más extenso de forámenes (97 %) se localizó superomedialmente al foramen infraorbitario, y solo dos (3 %) se ubicaron inferomedialmente. La predicción de la posición puede contribuir a una mejor comprensión de las variaciones anatómicas en la región infraorbitaria y a una localización más precisa del FIOA.

**PALABRAS CLAVE: Foramen infraorbitario accesorio; Tomografía computarizada; Análisis morfométrico; Importancia clínica.**

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