Analysis of Anatomical Characteristics and Morphometric Aspects of Infraorbital and Accessory Infraorbital Foramina

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Objective: This study aimed to perform a morphological and morphometric study of the characteristics of the infraorbital foramen (IOF) and accessory infraorbital foramen (AIOF) in Brazilian skulls.

Methods: A sample calculation determined a total of 94 human skulls to be evaluated by a trained examiner for number, shape, diameters, and location of IOF in relation to anatomical landmarks. Number, size, shape, diameters, location, orientation, position, and distances in relation to anatomical landmarks were evaluated for the AIOF. Descriptive analysis, paired *t* test, Wilcoxon test, Pearson and Spearman correlations were used.

Results: A total of 188 IOFs and 48 AIOFs were found. Circular outline was the predominant shape for both IOFs and AIOFs. Infraorbital foramens presented in left sides had a significantly greater transverse diameter and distance from medial margin of the orbit when compared with IOFs located on the right sides ($P < 0.001$). Accessory infraorbital foramens were most frequently found on the left sides of the skulls and had a superomedial position in relation to the IOFs. Accessory infraorbital foramens located on right sides had a significantly greater distance to anterior nasal spine when compared with AIOFs located on the left sides ($P < 0.001$).

Conclusions: The results of this solid methodology-based study can help guide surgeons in accurately locating the IOF and AIOF, and consequently, their neurovascular bundles to perform safe procedures during maxillofacial interventions.

Key Words: Accessory infraorbital foramen, anatomy, infraorbital foramen, skull

(*J Craniofac Surg* 2017;28: 528–533)

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Received June 4, 2016.
Accepted for publication August 30, 2016.

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This study was supported by CAPES/Brazil (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) and FAPEMIG (Fundação de Amparo à Pesquisa do Estado de Minas Gerais).
The authors report no conflicts of interest.

ISSN: 1049-2275
DOI: 10.1097/SCS.0000000000003235

One of the most basic principles in surgery is to avoid injuring important anatomic structures during surgical management of any patient.[1] In this regard, the infraorbital foramen (IOF) is a noble structure of enormous relevance in diverse branches of Medicine, such as otorhinolaryngology, ophthalmology, plastic surgery, and dentistry, taking the example of oral and maxillofacial surgery. This foramen is considered an important surgical parameter for external access to the maxillary sinus (CaldwellLuc).[2] Besides that, the identification of the IOF is clinically important to avoid local injury to the neurovascular bundle during maxillofacial procedures and also to perform effective nerve blocking to anesthetize the lower eyelid, upper lip, lateral nose, upper incisors, canine, and related gingivae.[3–5] Additionally, studies have shown that neurotomy of the infraorbital nerve (ION) with radiofrequency ablation was useful and less invasive for patients with trigeminal neuralgia.[6–8]

Several authors have also described the presence of an accessory infraorbital foramen (AIOF),[4,9–12] through which a branch of the ION passes.[4] A recent systematic review showed that the frequency of skulls containing the AIOF ranged from 0.8% to 27.3%, with a mean frequency of 16.9 ± 8.6%.[13] The comprehension of the anatomical localization of this supernumerary foramen acquires significant importance for surgeons because injury to any branch can result in sensory deficit.[14] In addition, a partial nerve blockade during anesthesia can lead to an insufficient blockage of the ION,[14] which can compromise the outcome of the surgical procedure. Therefore, an accurate knowledge regarding the identification, location, and comprehension of some characteristics of the IOF and AIOF (such as frequency, shapes, diameters, and distances from other important anatomical landmarks) is fundamental to aid diagnosis, treatment planning and to achieve excellence during diverse surgical procedures. Despite its clinical significance, there is a scarcity of data on the anatomical and morphometric aspects of AIOF. Furthermore, a critical analysis of the few studies reporting the presence of the AIOF reveals that most of them are rather descriptive and lack more refined methodology and statistical analyses, emphasizing the need for better structured studies in this issue.

Therefore, the aim of this present study was to perform a morphological and morphometric study of the characteristics of the IOF and AIOF in dry skulls of Brazilian individuals based on a solid methodology.

METHODS

A total of 94 human adult dry skulls of undetermined age and gender were collected from the Laboratory of Human Anatomy, Department of Morphology, Biological Sciences Institute, Federal University of Minas Gerais, Brazil and were used for anatomical and morphometric study. This research was carried out in compliance with international statutes and national legislation on ethics in research.

To calculate the sample size, a prevalence of 17% of AIOF,[13] a 95% confidence interval, and 8% standard error were considered, which determined a minimum sample of 85 skulls. Over 10% was added to compensate for any possible data loss, resulting in a total sample of 94 skulls.

Prior to the data collection, the examiner underwent a training exercise to define the better approach to perform an accurate measurement of the anatomic structures. Next, a pilot study was performed with human skulls (not part of the main study) to test and adjust the methodology.

The data collection procedure was carried out cautiously, with a tight control on the acquisition of data. Each skull was identified with a unique number to avoid obtaining duplicated data. All measurements were acquired in millimeters using a digital caliper (Mitutoyo, UK) and obtained by a single trained examiner to avoid intra and interexaminer (if more than 1 examiner would be used) discrepancies in data collection. The skulls were measured on both right and left sides.

Each skull was examined by several parameters, in order to precisely locate and characterize both IOFs and AIOFs. The following parameters were used to evaluate the IOFs: number, shape, transverse, and vertical diameters; transverse diameter of the orbit (TDO); distance from IOF to the medial margin of the orbit (MMO), being denominated DIOFMMO (in this case, a longitudinal imaginary line was drawn passing by the MMO and the distance was obtained from the IOF until the intersection with the line) and distance from IOF to the infraorbital margin (IOM), being denominated DIOFIOM (Fig. 1).

In addition, the following anatomical aspects of the AIOFs were evaluated: presence or absence, number, size, shape, orientation, and position. When the AIOF was present, measurements of the distances between this foramen from other important facial structures (frontomaxillary suture, zygomaticomaxillary suture, canine eminence, IOM [distance being denominated DAIOFIOM], IOF [distance being denominated DAIOFIOF] and anterior nasal spine) were held (Fig. 1).

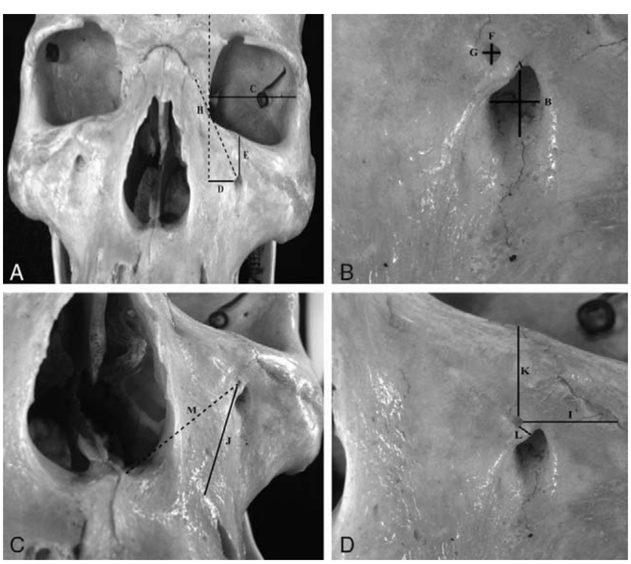

FIGURE 1. Parameters used to evaluate IOFs and AIOFs. A is vertical diameter of IOF; B, transverse diameter of IOF; C, transverse diameter of the orbit (TDO); D, distance from IOF to the medial margin of the orbit (MMO) (DIOFMMO); E, distance from IOF to the infraorbital margin (IOM) (DIOFIOM); F, vertical diameter of AIOF; G, transverse diameter of AIOF; H, distance from AIOF to frontomaxillary suture; I, distance from AIOF to zygomaticomaxillary suture; J, distance from AIOF to canine eminence; K, distance from AIOF to IOM (DAIOFIOM); L, distance from AIOF to IOF (DAIOFIOF); M, distance from AIOF to anterior nasal spine. AIOF, accessory infraorbital foramen; DAIOFIOF, distance from accessory infraorbital foramen to the infraorbital foramen; IOF, infraorbital foramen; MMO, medial margin of the orbit; TDO, transverse diameter of the orbit.

Data were digitized and organized in the software Statistical Package for Social Sciences (SPSS for Windows, version 20.0; SPSS Inc, Chicago, IL). Statistical analysis involved frequency distribution and association tests. Kolmogorov–Smirnov for data relating to the IOFs (sample size >50) and Shapiro–Wilk for data relating to AIOFs (sample size <50) normality tests were performed to verify the normality of data distribution. According to the results of these tests, parametric (paired *t* test and Pearson correlation) and nonparametric (Wilcoxon test and Spearman correlation) tests were used in the comparison and correlation analyses between the dependent variable and the independent variables. Also, mean (SD) and median (25th–75th) values were used depending on the normality of data. P values <0.05 were considered statistically significant.

RESULTS

Infraorbital Foramen

A total of 188 IOFs (94 foramina in each side) were found in the 94 skulls analyzed in this present study. It was observed that the circular outline was the predominant shape of IOF on both right and left sides, followed by oval and semilunar outlines (Table 1). Table 2 presents the values (in millimeters) of important parameters relating to the diameter of IOFs and distance from IOF to relevant anatomic landmarks. These measurements also allowed a comparison of IOFs values on the right and left sides of the skulls. In this regard, it could be noted that IOFs presented in the left sides had a significantly greater transverse diameter, TDO and DIOFMMO when compared with IOFs located on the right sides (P <0.001) (Table 2). Also, significant positive correlations were found between the IOF parameters—diameter and distances—measured in the right and left sides of the skull (P <0.05) (Table 3). Figure 2 summarizes the main mean values found for IOF measurements on the right and left sides.

Accessory Infraorbital Foramen

A total of 48 AIOFs were found in the 94 skulls analyzed in this present study, being 23 (47.92%) on the right side and 25 (52.08%) on the left side. Considering that the 94 skulls have a total of 188 sides (right and left), the total of 48 AIOFs represents a prevalence of 25.5% of AIOF in this current study. Regarding the shape of AIOF (Table 4), the AIOFs presented on the right side were predominantly circular (65.22%), followed by oval (34.78%) outline. However, in this same side, no AIOF with semilunar shape has been identified. On the left side, there was an equal distribution of

TABLE 1. Shape of Infraorbital Foramen, Considering the Right and Left Sides of the Skulls

	Infraorbital Foramen	
	Right	Left
Shape	n (%)	n (%)
Oval	29 (30.85)	26 (27.65)
Semilunar	16 (17.02)	13 (13.82)
Circular	49 (52.13)	55 (58.53)
Total	94 (100.0)	94 (100.00)

TABLE 2. Infraorbital Foramen Diameters and Distances From Infraorbital Foramen to Anatomical Landmarks Regarding Right and Left Sides of the Skulls

Infraorbital Foramen			
	Right	Left	
Parameters	Mean (SD), mm	Mean (SD), mm	P
TDO	35.60 (2.00)	36.39 (2.23)	<0.001*
DIOFMMO	11.52 (2.12)	12.78 (2.50)	<0.001*
DIOFIOM	6.35 (1.84)	6.57 (1.77)	0.060*
	Median (25th–75th), mm	Median (25th–75th), mm	
Transverse diameter	3.09 (2.52–3.87)	3.87 (3.33–4.28)	<0.001†
Vertical diameter	3.73 (3.28–4.24)	3.71 (3.07–4.16)	0.309†

DIOFIOM, distance from infraorbital foramen to the infraorbital margin; DIOFMMO, distance from infraorbital foramen to the medial margin of the orbit; TDO, diameter of the orbit.
*Paired *t* test ($P < 0.05$).
†Wilcoxon test ($P < 0.05$).

oval and circular outlines (n = 12, 48.00%) and only 1 AIOF with semilunar outline (n = 1, 4.00%) was identified.

Also, these supernumerary foramina were evaluated regarding their orientation and position (Table 5). It was observed that most of the foramina presented an inferior and medial orientation on both sides of the skulls. Regarding the position of AIOF, it was found that most of AIOFs had a superior and medial position in relation to the IOF, on both right and left sides. The inferior and medial position was the second most frequently AIOF position found on both sides of the skull.

Just as held for IOFs, a measurement of the vertical and transverse diameters of AIOFs and the distance from AIOF to important anatomical landmarks was done. The mean and median values (in millimeters) of these measurements are presented in Table 6. It could be observed that AIOFs located on the right sides had a significantly greater distance to anterior nasal spine when compared with AIOFs located on the left sides ($P < 0.001$) (Table 6). Besides that, no significant correlations were found between the AIOFs parameters—diameter and distances—measured on the right and left sides of the skull ($P > 0.05$)

TABLE 3. Correlation for Infraorbital Foramen Diameter and Distances From Infraorbital Foramen to Anatomical Landmarks Regarding Right and Left Sides of the Skulls

Infraorbital Foramen		
	Right Left	
Parameters	Correlation (*r*)	P
Transverse diameter	0.506	<0.001*
Vertical diameter	0.247	0.016*
TDO	0.641	<0.001†
DFIOMMO	0.538	<0.001†
DIOFIOM	0.808	0.001†

DIOFIOM, distance from infraorbital foramen to the infraorbital margin; DIOFMMO, distance from infraorbital foramen to the medial margin of the orbit; TDO, diameter of the orbit.
*Spearman correlation ($P < 0.05$).
†Pearson correlation ($P < 0.05$).

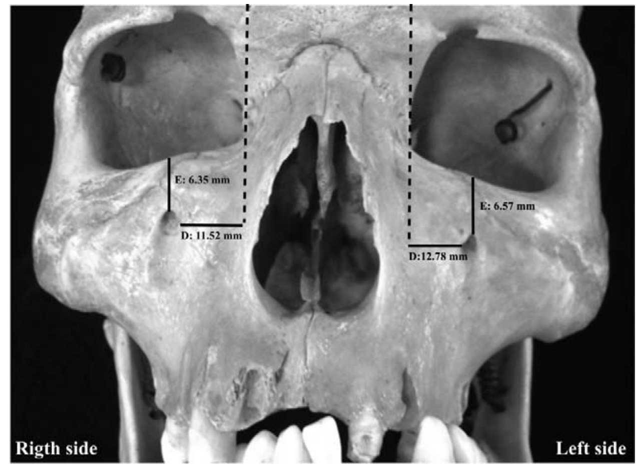

FIGURE 2. Mean values found for IOF measurements on the right and left sides. D is distance from IOF to the medial margin of the orbit (MMO) (DIOFMMO); E, distance from IOF to the infraorbital margin (DIOFIOM). IOF, infraorbital foramen.

(Table 7). Figure 3 summarizes the main mean or median values found for AIOF measurements on the right and left sides.

DISCUSSION

This present study was conducted to perform morphological and morphometric analyses of the IOF and AIOF in human dry skulls utilizing a meticulous methodology. A sample size calculation, examiner training, pilot study, and statistical analyses are examples of methodological aspects that confer credibility and reliability to the results found in this present study. It is important to mention that the previous published studies in this issue did not perform such solid methodology. Also, this study added measurements from IOF and AIOF to important anatomical landmarks, such as canine eminence, not yet described in previous studies.

The results of this present study can help guide surgeons in locating the IOF and AIOF, and consequently, their neurovascular bundles. Minor surgical procedures involving the soft tissues of the nose, cheek, lower and upper eyelid, and the maxillary incisors teeth are frequently performed by regional block anesthesia of the ION.[15] Regional nerve blocks are safe, easy to perform, and lead to less tissue swelling at the operative site, which provides good intraoperative conditions and decreases the total use of local anesthetic agent.[16] In fact, it is seen that the precise knowledge of the location of these foramina is crucial for carrying out effective regional nerve block anesthesia and the surgical procedures involving this anatomic area.[2,15] Also, diverse surgical treatments such as rhinoplasty, Caldwell-Luc operations, tumor surgery, reduction of the orbital floor (blow-out) and malar fractures, and the Le Fort I type

TABLE 4. Shape of Accessory Infraorbital Foramen, Considering the Right and Left Sides of the Skulls

Accessory Infraorbital Foramen		
	Right	Left
Shape	n (%)	n (%)
Oval	8 (34.78)	12 (48.00)
Semilunar	0 (0.00)	1 (4.00)
Circular	15 (65.22)	12 (48.00)
Total	23 (100.0)	25 (100.0)

TABLE 5. Distribution of Accessory Infraorbital Foramen in Relation to Orientation and Position on Right and Left Sides of the Skulls

Accessory Infraorbital Foramen		
	Right	Left
Orientation	**n (%)**	**n (%)**
Superior	0 (0.00)	0 (0.00)
Inferior	0 (0.00)	1 (4.00)
Medial	0 (0.00)	0 (0.00)
Lateral	0 (0.00)	0 (0.00)
Superior and medial	0 (0.00)	0 (0.00)
Inferior and medial	23 (100.00)	24 (96.00)
Position	**n (%)**	**n (%)**
Superior	0 (0.00)	0 (0.00)
Inferior	4 (17.39)	2 (8.00)
Medial	1 (4.34)	0 (0.00)
Lateral	0 (0.00)	0 (0.00)
Superior and medial	13 (56.52)	20 (80.00)
Inferior and medial	5 (21.75)	3 (12.00)

osteotomies may result in an iatrogenic injury to IOF neurovascular bundle.[15,17,18] According to Cutright et al,[1] the best technique to avoid damage to these structures is to know their exact location, highlighting even more the importance of being aware with the characteristics of these structures. Besides that, modern surgical procedures to the craniofacial region demand more precise understanding of the surrounding anatomy, thus data on morphometric measurements regarding reference landmarks are need reduce risks during surgical operations.[4,19]

In this current research, the predominant shape of IOFs was the circular outline, which is in accordance with the previous results.[15] On the other hand, Aggarwal et al[5] identified the oval outline as the predominant shape in Indian skulls, followed by circular outline, showing variability in facial bone openings depending on the population studied. The knowledge of the morphology of these foramina is mainly significant to surgeons and anesthetists to achieve a precise insertion of the needle.

TABLE 6. Accessory Infraorbital Foramen Diameters and Distances From Accessory Infraorbital Foramen to Anatomical Landmarks Regarding Right and Left Sides of the Skulls

Accessory Infraorbital Foramen			
	Right	Left	
Parameters	**Mean (SD), mm**	**Mean (SD), mm**	***P***
Vertical diameter	1.40 (0.56)	1.19 (0.62)	0.238*
Frontomaxillary suture	31.47 (9.88)	28.78 (7.00)	0.218*
Zygomaticomaxillary suture	22.48 (10.30)	24.88 (5.98)	0.301*
Canine eminence	27.27 (7.25)	25.85 (5.75)	0.499*
DAIOFIOM	13.09 (6.33)	12.58 (4.83)	0.735*
	Median (25th–75th), mm	**Median (25th–75th), mm**	
Transverse diameter	1.23 (0.79–2.11)	1.66 (1.08–2.14)	0.323†
Anterior nasal spine	32.49 (30.25–36.75)	28.60 (26.62–32.23)	0.001†
DAIOFIOF	7.68 (1.29–16.76)	6.12 (2.54–13.32)	0.607†

DAIOFIOF, distance from accessory infraorbital foramen to the infraorbital foramen; DAIOFIOM, distance from accessory infraorbital foramen to the infraorbital margin.

*Paired *t* test ($P < 0.05$).

†Wilcoxon test ($P < 0.05$).

Considering the importance of an accurate location and morphometry of the IOF, some parameters were measured, such as vertical and transverse diameters, TDO DIOFMMO and DIOFIOM on both sides of the skulls. The average values found for the transverse diameter was 3.24 mm to the right side and 3.90 mm to the left side, and 3.80 mm to the right side and 3.64 mm to the left side for the vertical diameter. Aggarwal et al[5] found similar results for the vertical diameter of IOF. Furthermore, statistical analysis of current data confirmed the presence of significant differences only for the transverse diameter between both sides of Brazilian skulls. The fact of verifying differences between the right and left sides for the transverse diameter denotes the need for greater attention in anesthesia application in the region. The shape of the foramina could be possibly associated with the difference in their transverse diameter.

In the present study, the measurement of the DIOFMMO was done in order to have a more accurate location of the IOF. Thus, TDO was primarily measured as a reference and then the DIOFMMO was measured. However, other studies used the facial midline as a reference landmark.[1,7,14,20] The choice for the measurement of TDO was due to the fact that it would allow a precise positioning of IOF, since using facial midline could not provide appropriate measurements if some anatomical structures (such as nasal septum) were not preserved. Also, the analysis of DIOFIOM showed average values of 6.35 mm and 6.57 mm for the right and left sides, respectively. In a study with American cadavers, Aziz et al[14] reported average values of 8.5 mm on both sides in male cadavers, and 7.6 mm (left side) and 8.1 mm (right side) in female cadavers. Despite no distinction between gender was done in this present study, it is perceptible the variety observed in the DIOFIOM in skulls of descendants of Brazilians and North Americans.

In addition to the IOF, it was essential to investigate the anatomical and morphological characteristics of AIOF, because of the inherent implications in the blockage of the accessory branch of the ION during surgical treatment planning. In the present study, it was found a prevalence of 25.5% of AIOF. Another Brazilian study found a prevalence of 21.6%,[21] which is similar to our findings. However, studies from different countries have reported

TABLE 7. Correlation for Accessory Infraorbital Foramen Diameter and Distances From Accessory Infraorbital Foramen to Anatomical Landmarks Regarding Right and Left Sides of the Skulls

Accessory Infraorbital Foramen		
	Right Left	
Parameters	**Correlation (*r*)**	***P***
Transverse diameter	−0.067	0.762†
Vertical diameter	0.063	0.781‡
Anterior nasal spine	0.137	0.532†
Frontomaxillary suture	0.347	0.114‡
Zygomaticomaxillary suture	0.193	0.378‡
Canine eminence	−0.151	0.492‡
DAIOFIOF	−0.023	0.913†
DAIOFIOM	0.222	0.309‡

DAIOFIOF, distance from accessory infraorbital foramen to the infraorbital foramen; DAIOFIOM, distance from accessory infraorbital foramen to the infraorbital margin.

†Spearman correlation ($P < 0.05$).

‡Pearson correlation ($P < 0.05$).

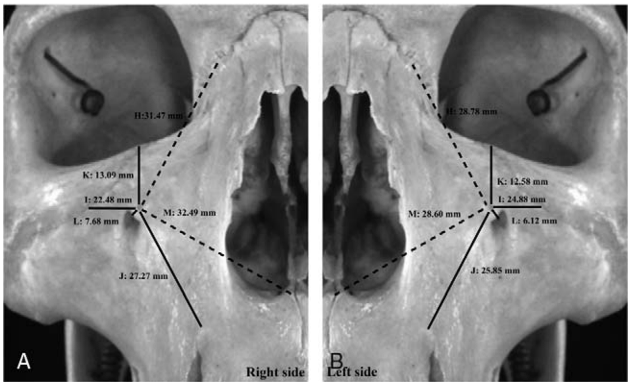

FIGURE 3. Mean or median values found for AIOF measurements on the (A) right and (B) left sides. H is distance from AIOF to frontomaxillary suture; I, distance from AIOF to zygomaticomaxillary suture; J, distance from AIOF to canine eminence; K, distance from AIOF to IOM (DAIOFIOM); L, distance from AIOF to IOF (DAIOFIOF); M, distance from AIOF to anterior nasal spine. AIOF, accessory infraorbital foramen; DAIOFIOF, distance from accessory infraorbital foramen to the infraorbital foramen; IOF, infraorbital foramen; IOM, infraorbital margin.

frequencies of AIOF ranging from 0.8% to 27.3%.[4,13,22] This can due to differences on population, origin and/or gender.[23]

Most AIOFs were located on the left side of the skulls. These findings are in accordance with the literature, since many reports also found similar results.[11,13,24–26] This result has an important meaning since it provides data to alert surgeons when performing surgeries on the left side of the face. Regarding to the shape of AIOF, the circular outline predominated on both sides of the skulls, which are in agreement with studies published by Tezer et al[25] and Gour et al.[26]

This present research also provided information about orientation and position of AIOF. The inferior and medial was the most found orientation. Other study found a downward direction as the predominant orientation.[4] The present results also showed that most of the AIOFs were located on the superomedial side of the IOF, corroborating data previously showed by several authors.[4,9,15] The relevance of knowledge about the occurrence and exact location of these supernumerary foramina are related to the potential risk of that iatrogenic morbidity during facial surgery without caution because of the extra branches of the nerve.[15] Also, anesthesia will not be sufficient if there is an accessory nerve. Although all fibers of the ION exit through the IOF, some fibers leave the nerve and exit separately through the AIOF.[5] During regional nerve block of the ION, these fibers can escape, preventing adequate analgesia or anesthesia.[5] For these reasons, a surgeon should be aware of this anatomic variation and should take it into consideration.[15]

It was also observed higher mean values for vertical and transverse diameters of the AIOFs on the left and right sides of the skulls, respectively. Tezer et al[25] observed a higher mean value in transverse diameter of AIOFs when compared with vertical diameters. Other measurements took into account important anatomical reference landmarks, such as DAIOFIOM, DAIOFIOF, anterior nasal spine, frontomaxillary, and zygomaticomaxillary sutures. In addition to these landmarks, the distance from AIOF to the canine eminence was also measured, which was not yet reported in other scientific works. The meritorious of measuring this distance relies on the fact that the canine eminence is the most prominent of the maxilla, and is an important reference landmark for the realization of the ION anesthetic technique.

The results of the present study demonstrated that there were morphological differences between right and left sides, reinforcing the knowledge that anatomical variations are relatively common in the human body. It is likely that the differences observed between the right and left sides, such as the DIOFMMO, reflect changes in the infraorbital nerve way within its channel, although such analysis was not evaluated. Ference et al[27] noted that IOFs whose nerves had a descending path inside the maxillary sinus were located at a lowest point in relation to the IOM than those whose nerves had a nondescending path, that is, the change in nerve path determined a difference in distance from the foramen to a particular bone accident. Interestingly, the distance from the AIOF to the anterior nasal spine was significantly higher on the right side when compared with the left side. Agthong et al[28] analyzed the same parameter in relation to IOF and did not obtain differences between the sides. However, the AIOF does not have a standardized position, as demonstrated in this present study, which could probably influenced the studied distances.

This study furnishes relevant and original informations about the anatomical characteristics and morphometric aspects of IOF and AIOF. However, it has limitations that should be noted. For example, no identification of race, gender, and age of the skulls were performed, which would give more details to the results.

CONCLUSIONS

Taken together, the data presented here highlights the importance of the detailed comprehension of the anatomical and morphometric characteristics of IOF and AIOF for surgical planning, since it can determine the difference between success and failure of the treatment approach.

ACKNOWLEDGMENTS

The authors would like to express immense gratitude to cadavers and their families, which made possible the realization of this study.

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