BIOSCIENCE JOURNAL

MORPHOMETRY OF THE INFRAORBITAL FORAMEN IN DENTATE AND EDENTULOUS ADULT HUMANS AND ITS CLINICAL RELEVANCE

João Gabriel ALEXANDER[1], Josemberg da Silva BAPTISTA[1]

[1] Laboratory of Applied Morphology – LEMA, Universidade Federal do Espírito Santo, Espírito Santo, Brazil.

Corresponding author:
Josemberg da Silva Baptista
josemberg.baptista@ufes.br

How to cite: ALEXANDER, J.G. and BAPTISTA, J.S. Morphometry of the infraorbital foramen in dentate and edentulous adult humans and its clinical relevance. *Bioscience Journal*. 2024, **40**, e40007. https://doi.org/10.14393/BJ-v40n0a2024-68149

Abstract
The infraorbital foramen (IOF) serves as an important anatomical reference for infraorbital nerve block during different procedures. Its clinical and surgical relevance, associated with conflicting results in its anatomy description justifies the present study. Thus, this work aims to describe the IOF, qualitatively and quantitatively, and propose an accurate measurement to define its location. One hundred and seventy-four IOFs of dry skulls were analyzed and divided in dentate (DE) and edentulous (ED) groups. Distances were measured between the IOF and the margin of the alveolar arch of the maxilla (MAAM), the inferior orbital margin (IOM), the intermaxillary suture (IMS), the vertical plane of IOF. A new methodology was proposed to optimize the identification of IOF based on the IMS distance. Oval-shaped IOFs (n=81/174) with inferomedial orientation (n=104/174) and with a crest-shaped upper margin (n=163/174) constituted the norm for this sample. Distance between IOF and MAAM was 29.97 ± 4.09 mm, to IOM 7.27 ± 1.8 mm, and to IMS 35.09 ± 3.77 mm. ED individuals had IOF closer to MAAM (p=0.0124). The highest point of this methodology was the lack of statistical differences in the IMS distance in ED and DE specimens, making this method applicable for both. Therefore, to minimize iatrogenic injuries, clinicians and surgeons must consider the total or partial presence of teeth, the methodology established to find the IOF, its inferomedial orientation, and the prevalent crest on its superior margin.

Keywords: Infraorbital foramen. Infraorbital nerve. Maxilla. Morphometry.

1. Introduction

The infraorbital foramen (IOF) is located in the superior region of the maxilla, inferior to the inferior margin of the orbit (IMO), and related to the most superior part of the zygomaticomaxillary suture, where the infraorbital artery, vein and nerve (IN) emerge (Zhang et al. 2019). It serves as an important anatomical and surgical reference for anesthesia, as well as for periorbital, oromaxillofacial, plastic and dental surgeries, and for IN radiofrequency neurotomy (Aggarwal et al. 2015; Ercikti et al. 2017; Zdilla et al. 2018). Precise knowledge of its location, morphology, and possible anatomical variations prevents neurovascular injuries in clinical-surgical procedures involving this region, and also guarantees safety during several surgeries in the anterior and orbital surfaces of the maxilla such as rhinoplasties, tumor surgeries, or Le Fort osteotomies type 1 (Gupta 2008; Ercikti et al. 2017; Zdilla et al. 2018).

Many studies have tried to promote ways to situate the IOF determining distances between the foramen and adjacent bone points, soft tissue structures, as well as anatomical planes. However, important inconsistencies have been observed in some results, especially due to anatomical references. To highlight the lack of standardization, upon analyzing the distance between IMO and IOF, Aziz et al. found a mean distance of 8.5 ± 2.2 mm, Ercikti et al. found 8.78 mm, while Aggarwal et al. described that the same distance was less than 5 mm (that, in 20.3% of cases) (Aziz et al. 2000; Aggarwal et al. 2015; Ercikti et al. 2017). Identifying the specific location of the IOF and performing a procedure based on certain types of anatomical landmarks can be a complex task, even for experienced physicians (Aggarwal et al. 2015). Hence, there is an urgent need for a standardized method to find the IOF followed by morphometric descriptions.

Considering only bony landmarks such as the nasospinale (NS – anterior nasal spine) and jugale (J) points, or the median line of the face disregarding soft tissues of the region such as muscles and the buccal fat pad, as well as variations in the midline or in the IOF, can lead to imprecision in clinical and surgical procedures in this region (Ercikti et al. 2017; Shin et al. 2020). Among other anatomical references, the extensive use of the maxillary dental arch as a basis for various techniques to block the IN, especially using the vestibular route, has also revealed great variation: Aggarwal et al. found that IOF was most commonly aligned to the second premolar (53.4%); Aziz et al. proposed that the first premolar (64%) was the most common in the American population (Aziz et al. 2000; Aggarwal et al. 2015). Thus, justified by the clinical and surgical relevance associated with conflicting results in the anatomy of the IOF, the aims of this study were to analyze the topography and the morphometry of the IOF, propose an accurate method that allows to identify its location, and verify differences between dentate (DE) and edentulous (ED) individuals.

2. Material and Methods

Specimens

The sample contained 101 dried skulls from the collection of the Department of Morphology of the Centro de Ciencias da Saude. All procedures were authorized by the Ethics Committee for Research with Human Beings via Plataforma Brasil (CAAE 32180520.0.0000.5060). Analysis of the specimens was performed at the Laboratory of Studies in Applied Morphology (LEMA) of the Department of Morphology. The sample included only adult skulls, indistinguishable from age and sexual characteristics. Initially, the IOF was identified in the maxilla, bilaterally, in relation to other adjacent structures: nasal notch, piriform aperture, zygomatic process of the maxilla, zygomaticomaxillary suture, IMO, canine fossa, and dental alveoli. Due to the improper condition and/or malformations, 14 skulls were excluded from the initial sample and 87 followed other stages of qualitative and quantitative analysis, resulting in the analysis of 174 IOFs.

Formation of the dentate (DE) and the edentulous (ED) groups

The sample was divided into DE and ED groups. The DE group was composed of hemicranium (both left and right) that necessarily contained the presence of the teeth or the dental alveoli corresponding to the maxillary incisors, canines and premolars. The ED group was composed of hemicranium (both left and right) that presented, as evidence of an antemortem process, the complete or partial absence (minimum 1 and maximum 3) of teeth or dental alveoli corresponding to the maxillary incisors, canines or premolars. The antemortem teeth loss was characterized by total closure of the dental alveoli. No total absence of teeth was recorded in the ED group.

Qualitative analysis

Specimens were described according to (Figure 1):

- Shape of the IOF: rounded, oval or fusiform;
- Orientation of the IOF: regardless of being right or left, it faced medial (nasal), inferomedial or inferior (labial);

• Characteristic of the superior margin of the IOF: either presence or absence of a crest on its superior margin;
• Presence of the accessory foramina.

Quantitative analysis

For quantitative analysis, a photographic stand with an attached camera (NEX-C3, Sony, Japan) was used. Samples were photographed in the frontal aspect of the cranium (centered in the internasal suture) as well as with a 30º-cranial inclination (centered in the intermaxillary suture) with a 10mm scale. Measurements were performed using a computer program (ImageJ, National Institutes of Health, United States of America) with individual scale calibration. The following distances were measured (Figure 1):

Front aspect of the cranium (standard):

• Distance between the margin of the alveolar arch of the maxilla (MAAM) and the IOF;
• Distance between the IMO and the IOF;
• Distance between the intermaxillary suture (IMS) and the vertical axis where the IOF is located. This measurement was performed over the margin of the alveolar arch of the maxilla using a millimeter paper ruler. In this way, the arcuate shape of this part of the maxilla was completely respected;

Front aspect of the cranium (30◦-cranial inclination):
• IOF area.

Analysis of results

Descriptive statistics were applied to qualitative data. For quantitative analysis, the normal distribution was ratified and a parametric statistical test was chosen to increase scientific rigor. The unpaired Student's T-test was chosen to analyze the comparison between DE and ED groups, regardless of the antimere, with a significance level of 0.05.

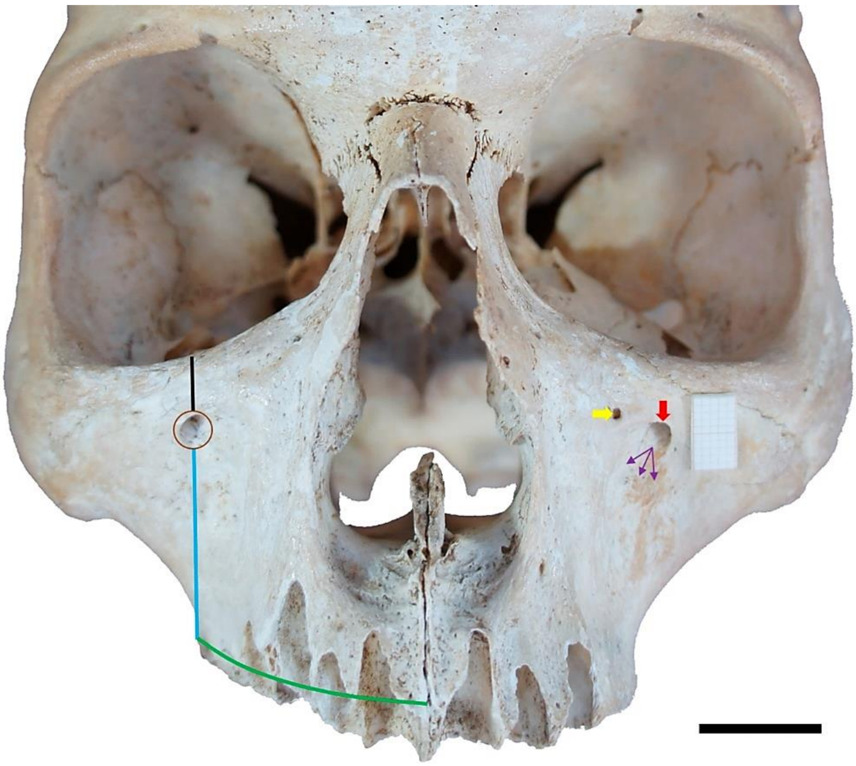

Figure 1. Demonstration of the parameters applied for qualitative and quantitative analysis. Brown circle: analysis of the infraorbital foramen shape; black line: distance between the infraorbital foramen and the inferior margin of the orbit; blue line: distance between infraorbital foramen and the margin of the alveolar arch of the maxilla; green line: distance between intermaxillary suture (passing above the alveolar

process) and the vertical axis where the infraorbital foramen is located; yellow arrow: analysis of the presence of the accessory infraorbital foramen (compare the antimeres); red arrow: analysis of the presence of the crest in the superior margin of the infraorbital foramen; purple arrows: infraorbital foramen orientation. Scale bar: 1.5cm.

3. Results

Qualitative analysis

Among the IOFs analyzed, 80 foramina belonged to the DE group and 94 belonged to the ED group. In both groups, IOFs were located in the maxilla, including the accessory IOFs, keeping an anatomical relationship medially with the nasal notch and the piriform aperture, superiorly with the IMO, laterally with the zygomatic process of the maxilla and zygomaticomaxillary suture, and inferiorly with the canine fossa and dental alveoli (Figure 2). Oval-shaped IOFs (n=81/174) with inferomedial orientation (n=104/174) and with a crest-shaped upper margin (n=163/174) constituted the norm for this sample. Tables 1 and 2 detail this data.

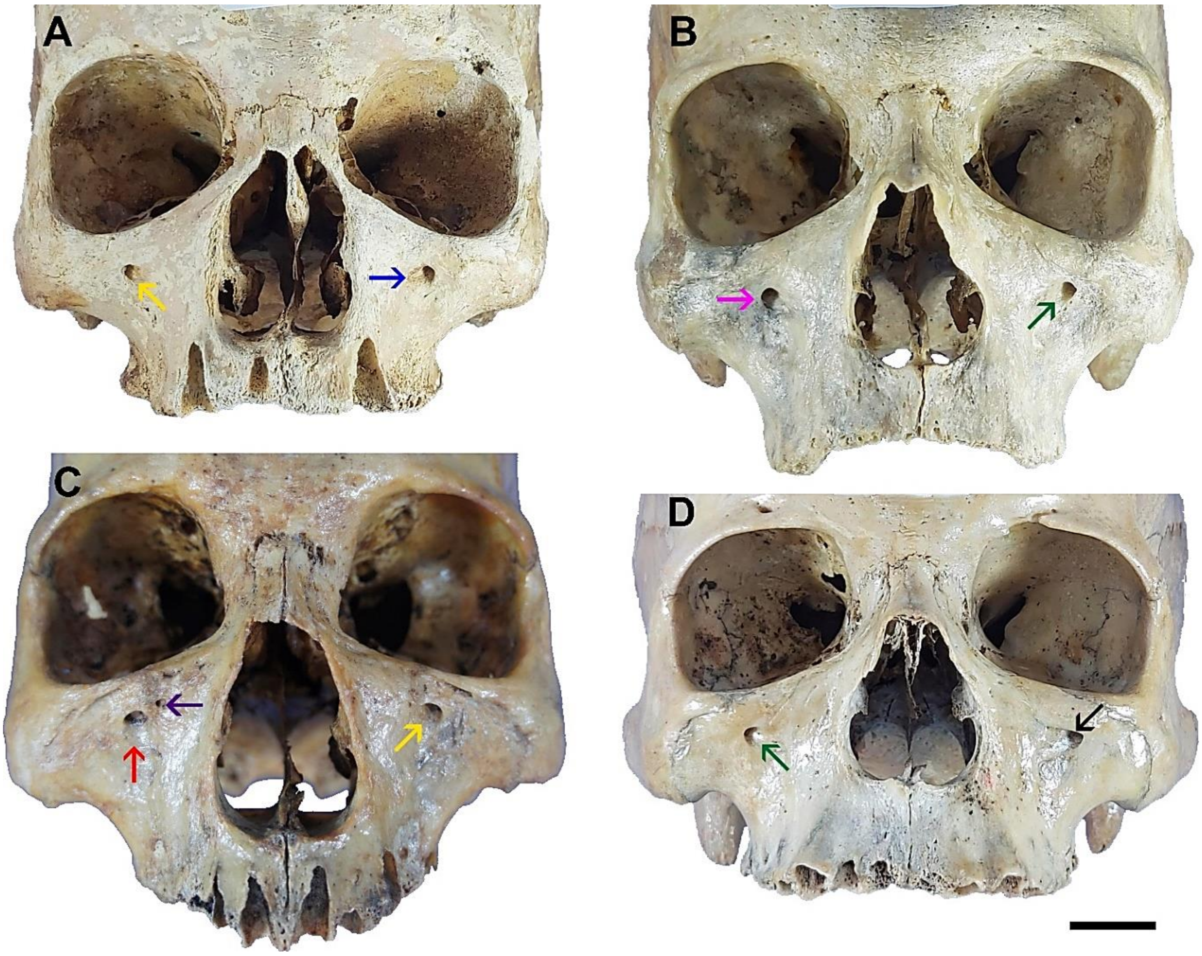

Figure 2. Representation of the qualitative data: images A and B are specimens of the ED group; C and D are specimens from the DE group. Purple arrow: accessory IOF. Yellow arrow: fusiform IOF. Pink arrow: rounded IOF. Blue arrow: oval-shaped IOF with medial (nasal) orientation. Red arrow: IOF with inferior (labial) orientation. Green arrow: IOF with inferomedial orientation. Black arrow: crest on the superior margin of the IOF. Scale bar: 3cm.

Table 1. Infraorbital foramen shape.

Shape	Left	Right	Total (n=174)
Oval	46	35	81
Rounded	30	37	67
Fusiform	11	15	26

Table 2. Infraorbital foramen orientation.

Orientation	Left	Right	Total (n=174)
Inferomedial	51	53	104
Inferior	21	19	40
Medial	15	15	30

Fourteen accessory foramina were identified, located superomedially in relation to the IOF, 9 belonging to the left antimere and 5 to the right antimere. Only 3 skulls showed bilateral presence of the accessory foramina. On both antimeres, approximately 46% of the sample (40 skulls of the 87 included) presented the same foramina in shape, in orientation and in the presence of crest on the superior margin of the IOF. Other skulls showed at least one difference between the 3 qualitative variables analyzed (Figure 3).

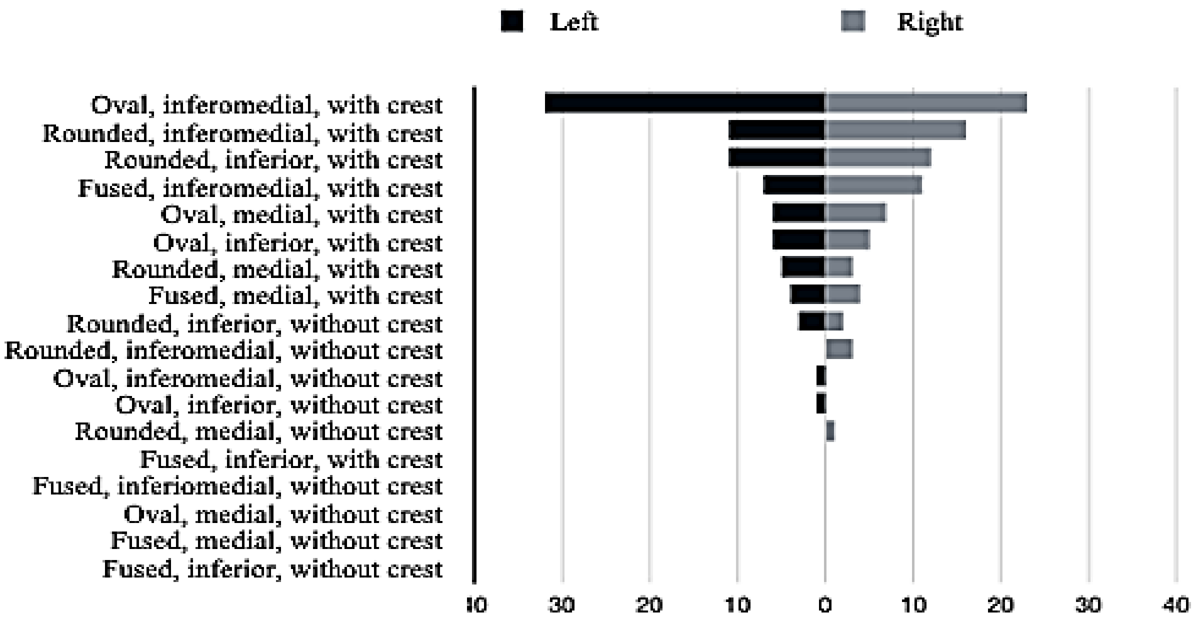

Figure 3. Qualitative analysis of the infraorbital foramina. All possible groupings of characteristics related to shape, orientation, and the presence of the crest in the infraorbital foramina are demonstrated, according to antimeres and order of prevalence.

Quantitative analysis

The mean, standard deviation and antimeres regarding the IOF measurement are available in Table 3. The DE group confirmed statistically a greater distance between the MAAM and the IOF compared to the ED group (Table 4). There were no other statistical inferences in measurements performed.

Table 3. General morphometry of the infraorbital foramina.

Measure (mm)	Left	Right	Mean
Area (mm^2)	5,15 ± 1,95	5,06 ± 2,05	5,11 ± 1,99
Distance MAAM to IOF	29,73 ± 3,82	30,22 ± 4,35	29,97 ± 4,09
Distance IMO to IOF	7,31 ± 1,85	7,23 ± 1,76	7,27 ± 1,8
Distance IMS to vertical axis of the IOF	36,01 ± 3,55	34,17 ± 3,78	35,09 ± 3,77

Table 4. Comparative morphometry of the infraorbital foramen between the dentate and the edentulous groups.

Measure (mm)	DE	ED	Mean difference	"p" value
Area (mm^2)	5,32 ± 2,03	4,93 ± 1,96	0,3850	p = 0.2064
Distance MAAM to IOF	30,81 ± 4,82	29,26 ± 3,20	1,549	p = 0.0124*
Distance IMO to IOF	7,39 ± 1,61	7,17 ± 1,95	0,2175	p = 0.4301
Distance IMS to vertical axis of the IOF	35,38 ± 4,33	34,84 ± 3,23	0,5471	p = 0.3427

4. Discussion

In the present study, a qualitative and quantitative description of the IOF in the DE and the ED individuals was performed in relation to adjacent bone structures. Morphometry allowed us to conclude that the IOF in ED specimens is closer to the MAAM compared to the DE specimens. Although the periodontal status and the maxillary bone loss could already have been proposed as factors that interfere in the situation of the IOF (Aggarwal et al. 2015), it had never been proven in the literature, making this result an unprecedented contribution. Considering the global prevalence of tooth loss at 2.4%, aggravated in third world countries (such as Brazil, at 3.9%), these findings become even more relevant in clinical-surgical practice (Kassebaum et al. 2014). Thus, in vestibular anesthesia in the IN, physicians and dentists should be aware of such data in order to achieve success in the procedure and avoid iatrogenic events.

Other IOF localization techniques are widely found in the literature. Most of them consider the following structures/regions individually: bone, joint and/or cartilaginous structures, such as ala of nose (AN), columella, anterior nasal spine/nasospinale point, zygomaticomaxillary suture, jugale point, and the median line of the face. However, these methodologies do not consider the topography of other facial structures such as the buccal fat pad, facial muscles, and variations in the structures in the median line of the face (Agthong et al. 2005; Gupta 2008; Chrcanovic et al. 2011; Singh 2011; Aggarwal et al. 2015; Zdilla et al. 2018a; Zdilla et al. 2018b). The major problem in these techniques is the disregard for their effective application in clinical practice: neglecting a deviation of the nasal septum (in the use of median line of the face), or considering zygomaticomaxillary suture or jugale point (points not easily palpable) makes clear how fragile the application of these methods are during procedures related to the IOF. This can lead to iatrogenic injuries and could increase the need for anesthetic agents followed by complications related to their use (Ercikti et al. 2017). For this reason, soft tissue landmarks could be viable options during surgeries, but there are still few studies with relevant samples using such landmarks (Ercikti et al. 2017; Shin et al. 2020).

The results allow for setting a protocol to situate the IOF using easily palpable bone landmarks in an attempt to overcome the possibility of interference from soft structures and other variables, aiming to transfer this knowledge to clinical practice in an accurate way. Therefore, a simple rule (made through a strip of graph paper) can be used to measure the distance between the IMS (passing above the alveolar process) and the vertical axis, where the infraorbital foramen is located (Fig. 1, Tab 3). Then, the approach must be through the vestibule mouth for the IF anesthesia, where the needle can be inserted at a depth of approximately 35mm accompanied by a supraperiosteal injection (or local infiltration). However, a shorter distance between MAAM and IOF in ED group must be considered. Contrasting the results of the present study and the observations from previous studies (Hindy and Abdel-Raouf 1993; Aziz et al. 2000; Apinhasmit et al. 2006; Gupta 2008; Aggarwal et al. 2015; Ercikti et al. 2017), the use of the IMS distance (based on the vertical plane of the IOF) brought precision and standardization to find the IOF. The highest point of this methodology was the lack of statistical differences in the IMS distance in ED and DE groups, regardless of sex, making this method applicable for both.

The morphometry of the IOF in relation to the MAAM and the IMO corroborated with other results found in the literature without statistical differences between antimeres. These results bring reproducibility of such measurements to clinical practice (Aziz et al. 2000; Kazkayasi et al. 2001; Brandão et al. 2008; Aggarwal et al. 2015; Ercikti et al. 2017). However, the IMO might not be such a reliable landmark to locate the exact position of the IOF given its characteristic (long curved line) prone to variations in the location of the IOF (Ercikti et al. 2017).

Although previous studies have discussed that the IOF has sufficient diameter for needle insertion, it is the measurement of its area and analysis of its shape that illustrate the real dimension of the opening region of the infraorbital canal (Aziz et al. 2000; Ilayperuma et al. 2010; Aggarwal et al. 2015). The predominance of an inferomedial orientation (93.67%) and the nature of the bone walls of the IOF bring practical implications that justify the superolateral orientation of the needle in vestibular anesthesia procedures, but without its insertion in the IOF. Thus, an adequate approximation to the IOF in order to acquire precise analgesia in the IN can be achieved safely, avoiding needle tapping into the IOF and iatrogenic injury to the IN. Yet, in anesthetic methods with the superior approach in the IOF, the prevalent crest in its superior margin must be considered as it can interfere in the success of the procedure (Aggarwal et al. 2015; Lee et al. 2006).

Incidence of single accessory IOFs and double accessory IOFs ranges from 2.2% to 18.2% and 0.5% to 1.28% respectively. Despite not identifying the latter, the sample applied in the present research corroborated with the former (8.04%). Although the anatomical norm establishes that all IN fibers emerge from the IOF, it is important to understand that some of those emerge separately from the accessory foramen, which could lead to inadequate analgesia and risk of injury. Health professionals must be aware of this possibility and the implications involved (Hindy and Abdel-Raouf 1993; Aziz et al. 2000; Kazkayasi et al. 2001; Bressan et al. 2004; Aggarwal et al. 2015).

This work has several limitations. Although characteristics regarding sex and age were identified in the sample, they were not sufficiently conclusive to allow subdivision of the sample, and this inhibited a direct relationship between these variables and the data obtained. Even though the use of dry skulls allowed for a reasonable sample, they do not belong to clinical practices, which deal with additional anatomical structures. The measurement proposed in the present research tries to overcome this limitation using anatomical references that are accessible through physical examination in an attempt to make it more applicable to clinical routines.

Although, in recent years, complementary methods have been developed to assist in approaching the IOF, it is not always feasible for being time-consuming and expensive, and also due to a shortage of equipment and qualified personnel (Aggarwal et al. 2015; Tsui 2009). When these are either not available or are contraindicated, it is necessary to know in-depth the characteristics and the anatomical relationships of the IOF. According to the most appropriate procedure to approach the IOF in adults, regardless of sex and race, the following features must be taken into account: the total or partial presence of the individual's dentition; its distance to MAAM, to IMO, to IMS; the prevalent crest in the superior margin of the IOF; and its inferomedial orientation.

5. Conclusions

In the present study, the topography and morphometry of the IOF were determined accompanied by differences between the DE and ED groups in this regard. Clinicians should be aware that the IOF is presented oval-shaped, with inferomedial orientation, and with a crest-shaped upper margin. Therefore, a small strip of graph paper can be applied to measure the distance between the IMS and the vertical axis where the IOF is located, without difference between ED and DE subjects. However, it has to take into account the shorter distance between MAAM and IOF in ED. Such data can lead to a more appropriate procedure to approach the IOF in adults, avoiding iatrogenic injuries to IN.

Authors' Contributions: ALEXANDER, J.G.: acquisition of data, analysis and interpretation of data, and drafting the article; BAPTISTA, J.S.: conception and design, analysis and interpretation of data, drafting the article, and critical review of important intellectual content. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: This work and all its procedures were authorized by the Ethics Committee for Research with Human Beings via Plataforma Brasil (CAAE 32180520.0.0000.5060). No consent to participate was needed.

Acknowledgments: The authors sincerely thank the donated bodies for science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude. Also, we would like to express their most sincere gratitude to the technicians of the Department of Morphology (Universidade Federal do Espirito Santo) for their support with the materials, and especially Dr. Willian Grassi Bautz (Ph.D.) from the Department of Morphology (Universidade Federal do Espirito Santo) for assisting with the methods of this study.

References

AGGARWAL, A., et al. Anatomical study of the infraorbital foramen. *Clinical Anatomy.* 2015, **28**(6), 753–760. http://doi.org/10.1002/ca.22558

AGTHONG, S., HUANMANOP, T. and CHENTANEZ, V. Anatomical variations of the supraorbital, infraorbital, and mental foramina related to gender and side. *Journal of Oral and Maxillofacial Surgery*. 2005, **63**(6), 800–804. http://doi.org/10.1016/j.joms.2005.02.016

APINHASMIT, W., CHOMPOOPONG, S., METHATHRATHIP, D., et al. Supraorbital Notch/Foramen, Infraorbital Foramen and Mental Foramen in Thais: anthropometric measurements and surgical relevance. *Journal of the Medical Association of Thailand = Chotmaihet Thangphaet*. 2006, **89**(5), 675–682.

AZIZ, S.R., MARCHENA, J.M. and PURAN, A. Anatomic characteristics of the infraorbital foramen: a cadaver study. *Journal of Oral and Maxillofacial Surgery*. 2000, **58**(9), 992–996. http://doi.org/10.1053/joms.2000.8742

BRANDÃO, F.H., MACHADO, M.R.C.S, AQUINO, J.E.P., et al. The Foramen and Infraorbital Nerve relating to the Surgery for External Access to the Maxillary Sinus. *Internal Archives of Otorhinolaryngology*. 2008, **12**(3), 342–346.

BRESSAN, S., GEUNA, S., MALERBA, G., et al. Descriptive and topographic anatomy of the accessory infraorbital foramen. Clinical implications in maxillary surgery. *Minerva Stomatologica*. 2004, **53**(9), 495–505.

CHRCANOVICA, B.R., ABREU, M.H.N.G., and CUSTÓDIO, A.L.N. A morphometric analysis of supraorbital and infraorbital foramina relative to surgical landmarks. *Surgical and radiologic anatomy*. 2011, **33**(4), 329–335. http://doi.org/10.1007/s00276-010-0698-1

ERCIKTI, N., APAYDIN, N., KIRICI, Y. Location of the infraorbital foramen with reference to soft tissue landmarks. *Surgical and radiologic anatomy*. 2017, **39**(1), 11–15. http://doi.org/10.1007/s00276-016-1683-0

GUPTA, T. Localization of important facial foramina encountered in maxillo-facial surgery. *Clinical Anatomy* (New York, N.Y.). 2008, **21**(7), 633–640. http://doi.org/10.1002/ca.20688

HINDY, A.M. and ABDEL-RAOUF, F. A study of infraorbital foramen, canal and nerve in adult Egyptians. *Egyptian Dental Journal.* 1993, **39**(4), 573–580.

ILAYPERUMA, I., NANAYAKKARA, G. AND PALAHEPITIYA, N. Morphometric Analysis of the Infraorbital Foramen in Adult Sri Lankan Skulls. *International Journal of Morphology*. 2010, **28**(3), 777–782. http://doi.org/10.4067/S0717-95022010000300019

KASSEBAUM, N.J, BERNABÉ, E., DAHIYA, M., et al. Global Burden of Severe Tooth Loss: A Systematic Review and Meta-analysis. *Journal of Dental Research*. 2014, **93**(7 Suppl), 20S-28S. http://doi.org/10.1177/0022034514537828

KAZKAYASI, M., ERGIN, A., ERSOY, M., et al. Certain anatomical relations and the precise morphometry of the infraorbital foramen--canal and groove: an anatomical and cephalometric study. *The Laryngoscope*. 2001, **111**(4 Pt 1), 609–614. http://doi.org/10.1097/00005537-200104000-00010

LEE, U-Y., NAM, S-H., HAN, S-H., et al. Morphological characteristics of the infraorbital foramen and infraorbital canal using three-dimensional models. *Surgical and radiologic anatomy*. 2006, **28**(2), 115–120. http://doi.org/10.1007/s00276-005-0071-y

SHIN, K-J., SHIN, H.J. and LEE, S-H. Location of the infraorbital foramen with reference to soft tissue landmarks for regional nerve blocks during midface surgery. *Clinical Anatomy*. 2020, **33**(8), 1159–1163. http://doi.org/10.1002/ca.23556

SINGH, R. Morphometric analysis of infraorbital foramen in Indian dry skulls. *Anatomy & Cell Biology*. 2011, **44**(1), 79–83. http://doi.org/10.5115/acb.2011.44.1.79

ZDILLA, M.J., RUSSELL, M.L., and KOONS, A.W. Infraorbital foramen location in the pediatric population: A guide for infraorbital nerve block. *Paediatric Anaesthesia*. 2018, **28**(8), 697–702. http://doi.org/10.1111/pan.13422

ZDILLA, M.J., KOONS, A.W., RUSSELL, M.L. The Infraorbital Foramen Is Located Midway Between the Nasospinale and Jugale: Considerations for Infraorbital Nerve Block and Maxillofacial Surgery. *The Journal of Craniofacial Surgery*. 2018, **29**(2), 523–527. http://doi.org/10.1097/SCS.0000000000004186

ZHANGE, K.R., BLANDFORD, A.D., HWANG, C.J., et al. Anatomic Variations of the Infraorbital Foramen in Caucasian Versus African American Skulls. *Ophthalmic Plastic and Reconstructive Surgery*. 2019, **35**(1), 25–28. http://doi.org/10.1097/IOP.0000000000001126

Received: 31 January 2023 | **Accepted:** 17 October 2023 | **Published:** 31 January 2024