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EVALUATION OF THE INFRAORBITAL COMPLEX BY DIRECT MORPHOMETRY

Maria Justina Roxana Vîrlan [1], Cătălina Murariu-Măgureanu [2], Simona Andreea Moraru [1], Vlad Iliescu [3], Ovidiu Romulus Gherghiţă [4], Vanda Roxana Nimigean [1], Ovidiu Muşat [5], Victor Nimigean [6]

[1] Oral Rehabilitation Department, Faculty of Dental Medicine, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania;
[2] Complete Denture Prosthodontics, Faculty of Dental Medicine, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania;
[3] Private Dental Practice, Bucharest, Romania;
[4] PhD student, Faculty of Dental Medicine, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania;
[5] Clinical Department of Ophthalmology, Dr. Carol Davila Central Military Emergency University Hospital, Bucharest, Romania;
[6] Anatomy Department, Faculty of Dental Medicine, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania.

Corresponding author: *Vanda Roxana Nimigean, Associate Professor, Head of Oral Rehabilitation Department, Faculty of Dental Medicine, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania, No 17-23 Calea Plevnei Street. E-mail: vandanimigean@yahoo.com*

ABSTRACT

The infraorbital complex belongs to the maxillary bone and it is an important landmark in dentistry, especially for loco-regional anaesthesia. For this study, bilateral measurements of the components of the infraorbital complex on twenty dry dentated human skulls were performed.
Results: the average length of the the infraorbital groove (IOG) was 12.55 mm and the average length of the infraorbital canal (IOC) was 12.92 mm. Regarding the infraorbital foramen (IOF), its shape was oval in 65% of the cases and the average distance between the infraorbital foramen and the inferior orbital margin (IOF-IOM distance) was 7.87 mm. IOF was located on the vertical line drawn between premolars in 50% of the cases and on the vertical line drawn through the axis of the maxillary second premolar in 45% of the cases.
The morphometric data obtained can be useful in dentoalveolar surgery.

Keywords: infraorbital groove, infraorbital canal, infraorbital foramen, loco-regional anaesthesia

INTRODUCTION

The infraorbital groove and canal are located on the orbital surface of the body of the maxillary bone, at the level of the orbital floor [1-3]. The infraorbital groove (IOG) is located posteriorly, it begins at the level of the inferior orbital fissure and it continues anteriorly with the infraorbital canal (IOC) [1-3]. The IOC opens on the anterior side of the maxilla through the infraorbital foramen (IOF), inferiorly to the infraorbital margin (IOM) [1-3]. IOG, IOC and IOF form the infraorbital complex containing the infraorbital neurovascular bundle [1-3]. The term infraorbital canal/groove complex (IOC/IOG complex) was first used by Scarfe WC et al. in 1998 [1-3]. We have also added the infraorbital foramen (IOF) to this complex, because

IOF represents the anterior opening of the IOC [1-3].

Some morphological variations have been described in the medical literature: the existence of the infraorbital groove only, the existence of the infraorbital canal only or the groove-canal combination [4-5]. In most of the cases the IOC is located within the superior wall of the maxillary sinus, but it can also show variations, and it may be partially or totally protruding into the maxillary sinus [4-5].

Moreover, other scientific papers have reported the existence of infraorbital accessory canals that open through accessory infraorbital foramina, containing nerves and vessels for the maxillary sinus, the teeth and the midfacial region [6-7]. Data from these studies indicate a fairly high prevalence of the infraorbital accessory canals, in over 50% of the cases [6-7].

The anterior and middle superior alveolar nerves detach from the infraorbital nerve in the infraorbital canal, and they descend towards the frontal teeth and towards the premolars, respectively, into the bone channels located in the anterior wall of the maxillary sinus [2]. The infraorbital canal creates an important prominence within the maxillary sinus cavity. Thus, a papyraceous, sometimes dehiscent plate, separates the nerve from the mucosa of the maxillary sinus, which explains the irradiated neuralgia in the innervation territory of the infraorbital nerve in the case of chronic odontogenic maxillary sinusitis [2].

Furthermore, IOF is a point of trigeminal peripheral emergence and at this level the loco-regional anaesthesia of the infraorbital nerve is performed [2]. Loco-regional anaesthesia of the anterior and middle superior alveolar nerves is performed within the IOC [2].

Precise localization of the infraorbital nerve in relation to easily measurable parameters may decrease the risk of damage to this nerve during regional surgery and may serve as a guide for local anaesthesia in dental medicine, ophthalmology, plastic surgery, rhinology, neurosurgery and dermatology [8].

Anaesthesia of the infraorbital nerve is required in the maxillary sinuses surgery and in the midface region surgery involving soft tissues of the nasal region, the cheek, lower eyelid and premolars, canines and maxillary incisors [8-9]. Moreover, infraorbital nerve anaesthesia is also needed for other procedures, like the treatment of fractures of the orbital floor, the reduction of fractures of the nasal bones or in the case of various facial skin cosmetic procedures [8-9].

The risk of damage to the infraorbital nerve and the vessels accompanying it during different therapeutic procedures exists because its trajectory is variable. Therefore, knowledge of the morphometric data on the anatomy of the groove, canal and infraorbital canal could reduce and even cancel this risk [8, 10-11].

This study presents a morphometric assessment of morphological variants of the infraorbital complex (IOG+IOC+IOF) on dry dentate human skulls and comparisons of the results obtained with those from other similar studies.

MATERIALS AND METHODS

Bilateral measurements on the groove, canal and infraorbital foramen on twenty dry dentate human skulls were performed for this study. The twenty dry dentate human skulls originated from the Romanian population and were provided by the Anatomy Department of the Faculty of Dental Medicine of the Carol Davila University of Medicine and Pharmacy in Bucharest, Romania. Because some of these skulls were not dated, their age and gender have not been taken into account.

The length of the infraorbital groove was measured, from the inferior orbital fissure to the place where it is continued by the infraorbital canal. The length of the infraorbital canal was analysed from the

anterior extremity of the infraorbital groove to the infraorbital foramen. Data were also gathered regarding the shape and diameters (transverse and vertical) of the infraorbital foramen, the distance from the infraorbital foramen to the inferior orbital margin (the distance from the infraorbital foramen to the infraorbital margin of the body of the maxilla, IOF-IOM distance), and the position of the infraorbital foramen in relation to the maxillary premolars.

The measurements were carried out by the same person with a Workzone digital calliper (Globaltronics GmbH, Singapore).

Furthermore, a systematic search in the medical literature was conducted in order to identify articles regarding the morphometry of the infraorbital complex. Twenty-five summaries of scientific works and fifty-nine in extenso articles published after 2000 were accessed through ISI Thomson Web of Knowledge and PubMed databases using the following keywords: infraorbital groove, infraorbital canal, infraorbital foramen, morphometry. Any type of article, case report, review or clinical study on human subjects was included. Additionally, a manual search in three books was performed. Of these scholarly papers, fifty were considered to be relevant for this study.

RESULTS AND DISCUSSION

The morphological landmarks measured and analysed in this study can be observed in the figure below, figure 1.

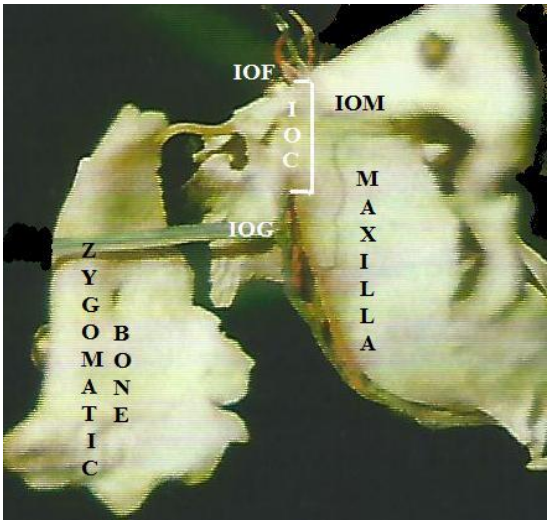

Fig. 1. The infraorbital complex:

IOG - the infraorbital groove and IOF - the infraorbital foramen,

and between them IOC - the infraorbital canal

Regarding the length of the IOG, the results of the measurements have shown relatively similar values on the left and on the right sides. On the right side the minimum value was 8.99 mm, the maximum value 16.15 mm and the average value 12.82 mm. On the left side the minimum value was 7.92 mm, the maximum value 16.21 mm and the average value 12.28 mm. The average value of the IOG length was 12.55 mm, bilaterally.

Concerning the length of the IOC, the results of direct measurements have also indicated relatively similar values on the left and right sides. On the right side the minimum value was 10.40 mm, the maximum value 16.56 mm, and the average value 12.86 mm. On the left side

the minimum value was 10.35 mm, the maximum value 17.46 mm, and the average value 12.98 mm. The average value of the length of the IOC, bilaterally, was 12.92 mm.

It can be observed that, from our data, the measured length of the IOG has values quite similar to those obtained for the IOC. The measured values for the IOC are slightly higher.

Overall, the total length of the IOG + IOC presented the following values: on the right side the minimum value was 19.32 mm, the maximum value 32.71 mm and the average value 26.01 mm, and on the left side the minimum value was 18.27 mm, the maximum value 33.67 mm and the average value 25.97 mm. The average value of the length IOG + IOC, on both sides (right/left), was 25.99 mm.

The results we have obtained present similarities, but also differences with those presented in other studies on this topic, as we will show below.

The average values, obtained in this study, regarding the total length of the IOC/IOG complex are close to those presented by Von Arx T and Lozanoff S, 2017 (average value between 25.4-31.9 mm) [4], Berge JK and Bergman RA, 2001 (average value of 27.7 mm) [12], and Abed SF et al., 2011 (average value of 25.4 ± 2.7 mm) [13].

Some authors use absolute values to describe the morphological proportions between the components and the total length of the IOC/IOG complex [14]. But, relative values of the measurements were used in this research. Therefore, the process of comparing the results obtained in this study with those from other papers is more difficult.

In the research conducted by Przygocka A et al., 2013 [3] the average length of the IOC/IOG complex on the right side was 27.78 ± 3.69 mm (standard deviation) and 28.06 ± 3.37 mm on the left side, respectively [3]. The authors described three types of IOC/IOG complex: type I, present in 11.4% of the cases, in which IOG represents one third of the total length of this complex, and the IOC represents two-thirds; type II, present in 68.6% of the cases, in which IOG is longer than one third and shorter than two-thirds compared to the total length of the complex, and the IOC represents minimum one third and maximum two-thirds of the total length of the complex and type III, present in 20% of the cases, in which the IOG is longer than two-thirds of the total length of the complex, and the length of the IOC is equal or less than one third of the total length of the complex [3].

But, in our study we observed a different morphological variant of the IOC/IOG complex than those described by Przygocka A et al., 2013: each part of the complex represents about half of its total length with an average value of 25.99 mm. The average length of IOG was 12.55 mm, while in the case of IOC, the average measured value was 12.92. These results are similar to those presented by Rahman et al., 2009 [15].

Type I of the IOC/IOG complex was presented by Przygocka A et al., 2013 [3] and by Kazkayasi et al., 2001 [16]. Type III was also reported by Hwang et al., 2013 [17].

The systematic search in the medical literature revealed different values of the length of the IOC/IOG complex. The lowest IOG length values, 4.6 ± 1.7 mm, were presented in the study conducted by Fontolliet M et al. 2019, [18], and the highest values of the IOG length were reported by Bahşi I et al., 2018 [8]. In the paper published by Bahşi I et al , 2018 [8], the measured length of IOG was 21.90 ± 3.57 mm on the right and 20.49 ± 3.49 mm on the left side for women, respectively, 23.28 ± 4.07 mm on the right and 21.97 ± 4.29 mm on the left side for men [8].

The lowest values of the length of the IOC, 8.45 ± 1.94 mm on the left and 8.20 ± 1.60 mm on the right for women, respectively, 8.37 ± 1.78 mm on the right and 8.45 ±

1.80 mm on the left for men, were also found in the study conducted by Bahşi I et al., 2018 [8]. The highest values of the IOC length were 22.95 ± 5.43 mm, in the study conducted by Kazkayasi M et al., 2001 [16].

Several authors emphasize the role of the infraorbital complex in surgery. A detailed knowledge of the anatomical morphometry in this area is required for the surgeon in order to perform many maxillofacial surgical procedures, as the region of the infraorbital complex is of great importance in surgical reconstructions [19-23].

Iatrogenic damage to the infraorbital nerve and accompanying vessels may occur during surgical procedures such as rhinoplasty, surgery of maxillary tumours and zygomatic fractures, Le Fort I osteotomy [24-25].

Regarding IOF, we obtained the following results:

- it presents an oval shape in 65% of the cases and a rounded shape in 35% of the cases, both on the right and on the left sides;
- its vertical diameter is variable, measuring between 3.2 - 5.3 mm;
- the transverse diameter of IOF is around 4.2-5.1 mm, taking into consideration the measurements on both sides left/right;
- regarding the distance from the infraorbital foramen to the inferior orbital margin (IOF-IOM distance), the following values were found: on the right side minimum 5.28 mm, maximum 9.3 mm and average 7.95 mm and on the left side minimum 5.63 mm, maximum 8.91 mm and average 7.80 mm, with differences of 0.4-1.7 mm between the left and right sides;
- in relation to the maxillary premolars, the IOF was located on the vertical line drawn between premolars in 50% of the cases; on the vertical line drawn through the axis of the maxillary second premolar in 45% of the cases and on the vertical line drawn through the axis of the maxillary first premolar in 5% of the cases. There were no significant differences between the left and the right sides.

The results we obtained on the morphometric evaluation of IOF show similarities and differences with those presented in other studies.

Regarding the shape of IOF, other studies have shown that the oval shape is more common. In the paper published by Singh R, 2011 [26], IOF has an oval shape in 71% of the cases. Kazkayasi M et al., 2001 [16], reported that IOF is oval in 34.3% of the cases, round in 38.6% of the cases and crescent-shaped in 27.1% of the cases.

The results regarding the IOF diameters from this study were comparable with other research articles on the same topic. Many research groups reported quite similar values of the IOF diameters: 3.6 ± 1.0 mm for the vertical diameter and 3.4 ± 1.3 mm for the horizontal diameter (Singh R, 2011 [26]), 5.0 ± 1.0 mm (Song WC et al., 2007 [27]), 3.7 ± 0.9 mm (Gupta T, 2008 [28]), 3.23 ± 0.81 mm (Chranovic BR et al., 2011 [29]), 3.5-4.5 mm (Cisneiros de Oliveira LC et al., 2016 [30]).

From all the reviewed articles on the topic of the IOC/IOG complex, only one single study reported much lower values than those presented in our study for the IOF diameters: Tashpinar C, in his study cited by Bahşi I et al., 2018 [8], found 1.71 ± 0.42 mm for the vertical diameter and 1.88 ± 0.44 mm for the horizontal diameter. We have not found any studies that show much higher values for the IOF diameters than those presented in our study.

Regarding the average distance between the infraorbital foramen and the inferior orbital margin (IOF/IOM distance), the values obtained in this study are comparable to those obtained by other research groups. Thus, Michalek P et al. 2013 [31] reported 7.6 ± 1.3 mm as the average distance between the infraorbital foramen and the inferior orbital margin. Chranovic BR et al., 2011 [29] obtained 6.41 ± 1.69 mm for the same

measurements (the average distance between the infraorbital foramen and the inferior orbital margin), Gupta T, 2008 [28] indicated 7.0 ± 1.6 mm, 7.45 ± 0.95 mm in the study carried out by Kazakayasi M et al., 2001 [16], 7.8 ± 0.2 mm in the study conducted by Agthong S et al., 2005 [32] and 7.50 ± 1.36 mm in the study performed by Tashpinar C, cited by Bahşi I et al., 2018 [8].

We have not found papers that show much lower values for the IOF-IOM distance. However, there are studies which report higher values of this distance, such as 9.6 ± 1.7 mm in the study performed by Hwang SH et al., 2013 [17], 9.3 ± 1.68 mm in the research conducted by Xu H et al., 2012 [33], and 9.23 ± 2.03 mm in the study carried out by Apinhasmit W et al., 2006 [34].

Interestingly, there are authors who have stated that the IOF-IOM distance increases when the IOC is prominent in the maxillary sinus [4].

The IOF-IOM distance is an important anatomical landmark for the localization of the IOF in loco-regional anaesthesia of the infraorbital nerve by extraoral approach [8, 35].

Also, knowing the IOF-IOM distance can be useful in identifying the danger zone during surgical procedures in case of fractures of the anterior and superior walls of the maxillary sinus [36].

Besides, the IOF relationship with the maxillary teeth is important for determining the position of the IOF for loco-regional anaesthesia of the infraorbital nerve and its alveolar intraoral branches [35].

Data from medical papers have shown different results on the relationship between IOF and the maxillary teeth. In the study published by Aziz SR et al., 2000 [37], IOF was most commonly located above the first premolar, in 64% of the cases on the right side and in 72% of the cases on the left side [37]. The same study reported the IOF location above the canine in 17% of the cases on the right side and in 8% on the left side [37]. The position of the IOF above the second premolar was found to be in 17% of the cases on the right side and in 17% of the cases on the left side [37]. The IOF above the first molar was described in 2% of the cases on the right side and in 3% on the left side [37]. These results are in contradiction with those presented in this paper and in the other studies used for comparison.

Gupta T, 2008 [28] reported the predominant location of the IOF (in more than 75% of the cases) as being above the second premolar or between the second premolar and the first molar, observations which are closer to our results. Similar findings are described by Aggarwal A et al., 2015 [38], which show that IOF is most commonly placed above the second premolar in 53.4% of cases. Also, Nanayakkara D et al., 2016 [39], have shown that IOF was located above the maxillary second premolar in 37.5% of the cases on the right side and in 55.9% of the cases on the left side, followed by a position between maxillary premolars in 34.4% of the cases on the right and in 26.5% of the cases on the left side.

Other frequent locations for IOF were between premolars in 21.8% of the cases and between the second premolar and the first molar in 17.3% of the cases [4].

These variable positions of the IOF in relation to the maxillary teeth can represent real causes for the failure of loco-regional anaesthesia of the infraorbital nerve by intraoral approach.

No significant differences between the right and left sides regarding the topographic anatomy of IOG, IOC and IOF have been found in our study, as well as in the studies used for comparison.

The particular morphological patterns at the level of the maxillary bone may suggest a certain predisposition towards pathological conditions or complications [40].

In order to reduce the failures of loco-regional anaesthesia in dental medicine, an important role lies in the knowledge of the different morphological patterns of the trigeminal peripheral emergence bone canals and foramina [41-45].

In vivo experimental human topographic models are closer to reality than experimental topographic animal models, the latter being more commonly discussed in the specialized literature [46-50]. Therefore, besides the knowledge on the above-mentioned morphological patterns, *in vivo* experimental human topographic models could prove beneficial for achieving therapeutic success.

CONCLUSIONS

In order to avoid neurovascular lesions at the level of the infraorbital complex, in-depth knowledge of the morphology and possible morphological variations regarding the floor of the orbital region is particularly important and necessary during surgical procedures at this level. Furthermore, a good understanding of the anatomical variations of the infraorbital region can improve the success rate of loco-regional anaesthesia of the infraorbital nerve and anterior and middle superior alveolar nerves in dental medicine.

Author contribution

Author #1 (Maria Justina Roxana Vîrlan) and author #2 (Cătălina Murariu-Măgureanu) have equal contributions to this paper and thus they are main authors.

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