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Assessment of the Presence of Infraorbital Foramen and Accessory Foramen in Adolescent and Adult Populations Using Cone Beam Computed Tomography

Adölesan ve Yetişkin Popülasyonlarda İnfraorbital Foramen ve Aksesuar Foramen Varlığının Konik Işınlı Bilgisayarlı Tomografi Kullanılarak Değerlendirilmesi

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ABSTRACT

Objectives: This study aimed to evaluate the vertical and horizontal dimensions, shape, anatomical location of the infraorbital foramen (IOF) and the presence of accessory infraorbital foramen (AIOF) in adolescent and adult individuals using cone-beam computed tomography (CBCT). Additionally, it aimed to contribute to clinical applications and address the lack of data on the adolescent population in the literature.

Materials and Methods: CBCT images of 1,000 patients who presented to the Department of Oral and Maxillofacial Radiology between 2021 and 2023 were retrospectively reviewed. A total of 315 individuals (193 males, 122 females) who met the inclusion criteria were included in the study. The dimensions of the IOF, its distances to adjacent anatomical landmarks, its shape, and the presence of AIOF were evaluated.

Results: In this study, IOF dimensions were larger in males, with the horizontal width greater on the right and the vertical height greater on the left. The most common IOF shape was circular, and accessory foramina were present in 31.6% of individuals, more frequently in males on the right. A statistically significant variation in the distance between the IOF and the midline (IOF-ML) with respect to age was observed on the right.

Conclusions: Detailed knowledge of the IOF's location, shape, and variations is crucial for preventing complications during surgical procedures, particularly infraorbital nerve blocks. The dimensions of the infraorbital foramen and its distances to anatomical landmarks in adolescents are generally similar to those in the adult population.

Keywords: Adolescent, adult, anatomic variation, cone-beam computed tomography, foramen

ÖZ

Amaç: Bu çalışma, konik ışınlı bilgisayarlı tomografi (KIBT) kullanılarak adölesan ve yetişkin bireylerde infraorbital foramenin (IOF) dikey ve yatay boyutlarını, şeklini, anatomik konumunu ve aksesuar infraorbital foramen (AIOF) varlığını değerlendirmeyi amaçlamıştır. Ayrıca, literatürde adölesan popülasyona dair veri eksikliğini gidermeye ve klinik uygulamalara katkıda bulunmayı hedeflemiştir.

Materyal ve Metot: 2021-2023 yılları arasında Ağız, Diş ve Çene Radyolojisi Anabilim Dalı'na başvuran 1.000 hastanın KIBT görüntüleri retrospektif olarak incelenmiştir. Çalışma dahil kriterlerini karşılayan toplam 315 birey (193 erkek, 122 kadın) çalışmaya dahil edilmiştir. IOF'nin boyutları, çevre anatomik yapılara olan mesafeleri, şekli ve AIOF varlığı değerlendirilmiştir.

Bulgular: Bu çalışmada, erkeklerde IOF boyutlarının daha büyük olduğu, yatay genişliğin sağ tarafta, dikey yüksekliğin ise sol tarafta daha fazla olduğu bulunmuştur. En yaygın IOF şekli dairesel olup, aksesuar foramenler bireylerin %31,6'sında, daha çok erkeklerde ve sağ tarafta gözlemlenmiştir. IOF ile orta hat (IOF-ML) arasındaki mesafenin yaşa göre sağ tarafta istatistiksel olarak anlamlı farklılık gösterdiği saptanmıştır.

Sonuç: IOF'nin yeri, şekli ve varyasyonları hakkında detaylı bilgi, özellikle infraorbital sinir blokları olmak üzere cerrahi prosedürler sırasında komplikasyonları önlemek için çok önemlidir. Adölesanlarda infraorbital foramenin boyutları ve anatomik dönüm noktalarına olan mesafeleri genellikle yetişkin popülasyondakilere benzerdir.

Anahtar Kelimeler: Adölesan, açıklık, anatomik varyasyon, konik ışınlı bilgisayarlı tomografi, yetişkin

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INTRODUCTION

The infraorbital foramen is an anatomical opening located in the maxillary bone through which the infraorbital nerve (ION), artery, and vein pass. The infraorbital nerve arised from the trigeminal ganglion and emerges through the IOF, providing sensory innervation to the upper cheek, lower eyelid, parts of the nasal region, upper lip, and maxillary sinus.[1,2]

One of the fundamental principles in surgical practice is to avoid injury to critical anatomical structures during any operative intervention. In this context, the IOF holds particular significance across various medical specialties, including otolaryngology, ophthalmology, plastic surgery, and dentistry, especially in oral and maxillofacial surgery. Additionally, it serves as a crucial landmark for accessing the maxillary sinus externally, as utilized in procedures like Caldwell-Luc surgery.[3-8]

ION block is crucial in performing these procedures. It also plays a significant role in postoperative pain management and the treatment of trigeminal neuralgia.[1-6]

An AIOF represents an anatomical variation characterized by a smaller aperture located near the primary IOF. This AIOF typically combines with either the infraorbital canal or the orbital floor. The ION is observed in four main branches: internal nasal, external nasal, lower palpebral and upper lip. The AIOF may transmit one or more of these branches.[3-7]

Consequently, precise knowledge of the IOF's anatomical location, its spatial relationships with adjacent structures, and its anatomical variations is of critical importance. Such knowledge is essential not only for the prevention of iatrogenic injury but also for improving the efficacy of regional nerve blocks in this area.[9]

Numerous studies have shown considerable changeability in the shape and location of the IOF among different populations and ethnic groups.[3,5,7,9,10]

This study aims to assess the vertical and horizontal dimensions, shape, and anatomical location of the IOF in adolescent and adult populations using CBCT, and to determine the prevalence of AIOF. The position, size, and variations of the IOF may change throughout the developmental process. Therefore, evaluating adolescent individuals—whose anatomical structures have not yet fully matured—is important for understanding age-related differences in IOF morphology. The data of our study will contribute to clinical practice by providing reference values for surgical procedures and will fill the data gap in the literature regarding the adolescent population.

MATERIALS AND METHODS

Ethics Committee Approval: Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Zonguldak Bülent Ecevit University (Date: 17.04.2024, decision no: 2024/07). This study was conducted in accordance with the World Medical Association's Declaration of Helsinki. All patients provided informed consent for the use of their radiographic data in scientific research.

Samples: The sample size was calculated using G*Power 3.1 software, based on a significance level of 5% ($\alpha = 0.05$), 80% statistical power ($1-\beta = 0.80$), and a medium effect size (Cohen's $d = 0.5$). Power analysis revealed that a minimum of 128 participants (64 per group) was required to detect statistically significant differences between two independent groups. In this study, CBCT images of 1,000 patients referred to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Zonguldak Bülent Ecevit University, for diagnostic purposes between 2021 and 2023 were retrospectively reviewed. A total of 315 patients (193 males, 122 females) aged between 10 and 74 years meeting the inclusion and exclusion criteria were included in the study. Thus, the power of the study was further increased. CBCT images were obtained using the Veraviewepocs 3D R100 / F40 tomography device (J. Morita Mfg. Corp., Kyoto, Japan) with an 8x10 cm field of view (FOV), 90 kVp, 5 mA, and a voxel size of 0.125 mm³. The CBCT images were analyzed using the i-Dixel 2.0 software (J. Morita Corporation, Osaka, Japan).

Inclusion Criteria: In order for patients to be included in the study, the following criteria were met:

- Their CBCT images were free of artefacts and distortions,
- They gave consent for their radiographic images to be used in scientific studies,
- They were of Turkish nationality.

Exclusion Criteria: Patients were excluded from the study if any of the following existed:

- They had cysts, tumors or craniofacial syndromes in the relevant anatomical region,
- They had prior orthodontic treatment or surgery in the area
- Their CBCT images contained artefacts that hindered evaluation.

In this study, the horizontal and vertical dimensions of the IOF were measured. To determine the anatomical location of the IOF, the distances between the IOF and the infraorbital margin (IOF-IOM), the lateral nasal wall (IOF-LNW), and the midline (IOF-ML) were measured. Additionally, the shape of the IOF was classified, and the presence of an AIOF was also evaluated. The images were evaluated once by consensus between a specialist in oral and maxillofacial radiology with seven years of experience and a research assistant with two years of experience. To assess interobserver reliability, 10% of the images were randomly selected and independently reviewed by both observers. Interobserver agreement was assessed using Kappa statistics, which demonstrated excellent concordance (κ=0.957, p<0.001). In cases of uncertainty, a second evaluator [Assoc. Prof. (G.G.)] was consulted to perform the additional assessment, and the examiners then engaged in further evaluations to reach a final consensus.

Statistical Analysis: Statistical analyses were performed using the SPSS software package, version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics, independent samples t-tests, and Chi-square tests were used for data evaluation. Interventional studies involving animals or humans, as well as other studies requiring ethical approval, must specify the approving authority and provide the corresponding ethical approval code. A significance level of p<0.05 was accepted as significant.

RESULTS

The mean age of the male participants was 47.6±14.1 years (range: 10–74 years), while the mean age for female participants was 44.87±16.2 years (range: 11–73 years). The horizontal dimension of the IOF was larger on the right side, whereas the vertical dimension was greater on the left side (Table 1).

Analysis of IOF shapes revealed that the most common shapes in both genders were circular, oblique oval, vertical oval, and horizontal oval, respectively (Table 2). A statistically significant difference was found between genders for both horizontal and vertical measurements bilaterally, with males having larger values in all parameters (p=0.0001) (Table 2). While significant differences favoring males were observed for the IOF-LNW and IOF-ML distances, no statistically significant difference between genders was found for the IOF-IOM distances (Table 3).

Table 1. Horizontal and vertical dimensions of the IOF and the mean age of the participants.

Parameter	Left Horizontal	Left Vertical	Right Horizontal	Right Vertical	Age of male	Age of female
n	315	315	315	315	193	122
Mean ±SD (mm)	3.86±0.59	4.24±0.65	3.87±0.55	4.20±0.56	47.6±14.1	44.87±16.2
Min-Max (mm)	2.39-6.11	2.56-7.32	1.96-5.61	1.87-6.00		

IOF; infraorbital foramen.

Table 2. Horizontal and vertical dimensions of the IOF.

	Horizontal Length Mean (mm)	Vertical Length Mean (mm)	Circular n (%)	Oblique Oval n (%)	Horizon-tal Oval n (%)	Vertical Oval n (%)	Total (n)
Male (n=193)	4.07	4.40	166 (43)	127 (32.9)	34 (8.8)	59 (15.3)	386
Female (n=122)	3.67	4.06	104 (42.6)	80 (32.5)	15 (6.1)	45 (18.8)	244
Total	3.87	4.23	270 (42.8)	207 (32.8)	49 (7.9)	104 (16.5)	630
p-value	**0.0001**	**0.0001**	0.172	0.346	0.991	0.456	

IOF; infraorbital foramen.

Table 3. Relationship between IOF position and gender.

Gender	Left Side IOF-IOM (mm) Mean ± SD	Left Side IOF-LNW (mm) Mean ± SD	Left Side IOF -ML (mm) Mean ± SD	Right Side IOF-IOM (mm) Mean ± SD	Right Side IOF-LNW (mm) Mean ± SD	Right Side IOF-ML (mm) Mean ± SD
Male (n=193)	8.36 ± 1.75	12.76 ± 2.74	27.25 ± 2.86	8.57 ± 1.88	12.34 ± 2.83	26.97 ± 2.78
Female (n=122)	8.42 ± 1.70	11.86 ± 2.74	26.13 ± 2.11	8.22 ± 1.67	11.28 ± 2.70	25.79 ± 2.45
Total	8.39 ± 1.73	12.41 ± 2.77	26.82 ± 2.64	8.44 ± 1.81	11.93 ± 2.82	26.50 ± 2.71
p-value	0.734	**0.004**	**0.0001**	0.098	**0.001**	**0.0001**

IOF-IOM: infraorbital foramen-infraorbital margin; IOF-LNW: infraorbital foramen-lateral nasal wall; IOF-ML: infraorbital foramen-midline.

Evaluation of the presence of AIOF revealed a total of 199 AIOFs (31.6%) among 315 individuals. A statistically significant difference was observed, with males demonstrating higher rates on the right side. (p = 0.012) (Table 4).
An analysis of the relationship between age groups and distances to anatomical landmarks revealed a statistically significant difference was found only for the IOF-ML distance on the right side (p =0.08). This difference was attributed to the higher mean values observed in the 50–64 age group and the lower values recorded in the 15–19 and 20–34 age groups (Table 5).

Table 4. Presence of accessory infraorbital foramen.

Gender	**Left Side,** n (%)	**Right Side,** n (%)	**Total,** n (%)
Male (n=193)	69 (50.0)	69 (50.0)	138 (35.7)
Female (n=122)	34 (55.7)	27 (44.3)	61 (25)
Total	103 (51.7)	96 (48.3)	199 (31.6)
p-value	0.178	0.012	

Table 5. Mean values of IOF dimensions and distances to anatomical landmarks by age groups.

Parameter	Side	10–14 years	15–19 years	20–34 years	35–49 years	50–64 years	65–79 years	p-value
Horizontal Length (mm)	Left	3.58±0.37	3.84±0.55	3.88±0.64	3.83±0.57	3.88±0.58	4.27±0.80	0.09
	Right	3.69±0.47	3.68±0.51	3.86±0.62	3.88±0.56	3.90±0.54	4.09±0.53	0.55
Vertical Length (mm)	Left	3.96±0.31	4.18±0.60	4.28±0.68	4.28±0.57	4.20±0.70	4.45±0.92	0.56
	Right	4.27±0.37	4.05±0.52	4.19±0.59	4.18±0.50	4.27±0.60	4.19±0.59	0.83
IOF-IOM Distance (mm)	Left	8.96±1.24	8.80±2.36	8.63±2.01	8.22±1.63	8.35±1.62	8.50±1.82	0.59
	Right	9.30±1.84	8.70±2.42	8.55±2.02	8.13±1.70	8.62±1.71	8.63±1.68	0.33
IOF-LNW Distance (mm)	Left	13.04±2.27	12.76±2.34	12.82±2.69	12.35± 2.73	12.27±2.93	12.07±3.02	0.65
	Right	12.70±2.76	12.31±2.61	12.48±2.74	11.76 ±2.70	11.75±2.98	12.40±3.28	0.22
IOF-ML Distance (mm)	Left	25.34±1.22	26.54±2.37	26.73±3.04	26.94 ±2.51	26.77±2.74	27.52±2.72	0.59
	Right	26.32±0.79	25.18±1.54	25.77±2.99	26.31 ±2.76	27.18±2.62	26.89±2.91	**0.008**

IOF-IOM: infraorbital foramen-infraorbital margin; IOF-LNW: infraorbital foramen-lateral nasal wall; IOF-ML: infraorbital foramen-midline.

DISCUSSION AND CONCLUSION

The morphometric characteristics of the IOF play a significant role in the application of anesthesia techniques targeting the ION.[11,12] Accurate localization of the IOF and understanding the orientation of the infraorbital canal are essential for achieving effective nerve blockade.[13] During surgical procedures, the neurovascular structures passing through the IOF may be damaged, leading to complications such as paresthesia or anesthesia.[14]
The studies conducted by Sokhn et al.,[5] Dağıstan et al.,[8] and Nanayakkara et al.[10] also investigated the horizontal and vertical dimensions of the IOF, reporting results similar to those found in the present study. However, while the first two studies did not find a statistically significant association between IOF dimensions and gender,[5,8] Nanayakkara et al., in a study on the Sri Lankan population, reported that males exhibited larger dimensions compared to females.[10] Our findings are consistent with the results of the latter study.
Previous research has shown varied results regarding the shape of the IOF. In the Indian population, the most common shape was vertical oval (42.7%),[15] while in the Sri Lankan population, the oval form was most frequently observed.[11] In a separate study on the Lebanese population, the circular shape was predominant (52.4%), consistent with the findings of our study.[5] In a study conducted on the Turkish population,[8] the shapes were generally classified into circular and oval categories, with the oval form being the most frequent (58%). However, upon closer examination, the oval category was further subdivided into oblique, vertical, and horizontal forms. From this perspective, the results of our study align closely with those in the literature. Although the most common shape in our study was circular (42.8%), the overall prevalence of the oval form—when all oval

subtypes are combined—is comparable to the results of other studies conducted on the Turkish population.

Shape variations of the IOF may lead to significant differences in clinical practice. Since the shape affects the size of the foramen and the direction of the nerve's emergence, it can directly influence the success of local anesthesia procedures. It has been reported that small and round foramina may complicate needle positioning, while larger or oval foramina may hinder achieving complete nerve block due to branching of the ION.[16-21]. Moreover, the shape and orientation of the IOF play a critical role in surgical planning.

In the study performed by Dağıstan et al.,[8] no significant association was found between gender and the distances from the IOF to the infraorbital margin, lateral nasal wall, and midline. However, in the study by Sokhn et al.,[5] similar to our findings, a statistically significant relationship was reported between gender and the distances of IOF-LNW and IOF-ML, with greater distances observed in males. Aggarwal et al.[16] reported an average IOF-ML distance of 25.69 ± 2.37 mm, while Gupta[17] found this value to be 28.5 ± 2.6 mm. These studies also found the measured distances to be significantly greater in males. In our study, no significant difference was found between genders regarding the IOF-IOM distance. However, the distances between the IOF-LNW, as well as the IOF-ML, were significantly greater in males. The higher mean values reported may be attributed to ethnic differences among populations.

The studies by Dağıstan et al.,[8] and Sokhn et al.[5] did not report any statistically significant relationship between age groups and the distances from the IOF to anatomical landmarks. In another study conducted by Lee et al., it was demonstrated that the location of the IOF varied between genders, and this variation primarily occurred during the early years of life, stabilizing after the age of 20.[6] In our study, no significant age-related changes in IOF location were observed, and the measured distances showed a similar distribution across all age groups. It is important to note that our sample consisted of individuals aged 10 years and older.

Studies analyzing the IOF and/or AIOF in the adolescent population (ages 10–19) using CBCT are limited.[6,18,19] In the study by Ali et al.,[18] an AIOF was detected in 29% of a patient population ranging in age from 16 to 85 years. In a study by Zdilla et al.,[19] which employed a completely different methodology, the location of the IOF was referenced relative to specific anatomical landmarks. It was reported that, regardless of age, the IOF is located approximately 2 mm from the midpoint between the nasospinale and jugale points. This finding may prove valuable in improving the accuracy of ION block procedures.

In adolescent individuals, the IOF may be positioned more superiorly or medially, which may necessitate adjustments in needle angulation during the administration of local anesthesia. Therefore, given the age -related variability in IOF morphology during adolescence, preoperative evaluation using CBCT is essential to enhance clinical success and minimize the risk of complications.[6,16-19]

It is evident from the literature that the reported prevalence of AIOF varies across different studies. Research conducted on Sri Lankan, Lebanese, Thai, and Iranian populations reported AIOF prevalence rates ranging from 7% to 9%.[5,10,20,21] In studies involving the Indian population, this prevalence was found to be between 20% and 29%.[18,22] Studies have reported highly variable rates in the Turkish population, ranging from 7% to as high as 56%.[7,8] In the present study, the prevalence of AIOF was determined to be 31%. Although these variations suggest that racial and ethnic factors may influence prevalence, the wide range of results reported within the Turkish population indicates that further studies with larger sample sizes are necessary to confirm the significance of ethnic factors in this regard. On the other hand, in our study, high-resolution images were obtained using a voxel size of 0.125 mm³. In the study by Çelebi et al.[7], images were acquired with a voxel size of 0.3 mm at 120 kVp and 5 mA. In the study by Dağıstan et al.,[8] the voxel size was not specified; however, the images were acquired at 110 kVp, up to 20 mA, and with a FOV of 16×18 cm. Differences in voxel size among the devices may lead to variations in detection sensitivity, particularly for small structures such as accessory foramina.

Measurements taken on dry skulls benefit from the absence of soft tissues, allowing clearer identification of bony landmarks, but they neglect soft tissue influence and in vivo artifacts On the other hand, CBCT provides high accuracy and reproducibility for 3D morphometric analysis, yet its precision is affected by soft-tissue attenuation, metal-induced artefacts, voxel resolution, and segmentation thresholding Moreover, CBCT-derived IOF measurements may differ from manual dry-skull measurements, potentially yielding higher mean values Recognizing these methodological differences is essential for interpreting morphometric data.[10,20,23]

This study also has certain limitations. Firstly, it has a retrospective design and is based solely on CBCT images obtained within a specific time frame at a single center, which may limit the generalizability of the results. Furthermore, only individuals of Turkish origin were included in the study; therefore, it is not possible to generalize the morphometric characteristics of the IOF to individuals of different ethnic backgrounds. The selection of 10 years as the lower age limit in this study was primarily based on anatomical and developmental factors. This dynamic development may hinder the standardization of measurements and reduce the reliability of the findings. Therefore, only adolescent and adult age groups were included in the study.

In conclusion, this study revealed that the morphometric characteristics of IOF are largely similar in adolescent and adult individuals. The data obtained may contribute to the safe and accurate localization of the IOF in clinical practice. Additionally, considering the results of this study, the presence of AIOF should be taken into consideration during anesthesia practices and especially during surgical procedures.

Ethics Committee Approval: Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Zonguldak Bülent Ecevit University (Date: 17.04.2024, decision no: 2024/07). This study was conducted in accordance with the World Medical Association's Declaration of Helsinki. All patients provided informed consent for the use of their radiographic data in scientific research.

Conflict of Interest: No conflict of interest was declared by the authors.

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