Retrospective Study

Study of Infraorbital Foramen Using 3-Dimensional Facial Bone Computed Tomography Scans

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Background: Previous studies of variations of the infraorbital foramen (IOF) demonstrated conflicting results regarding to the side and gender in which specific variations occur. Significant differences in some measurement points between genders have been found, whereas, other studies did not report such differences. The presence of an accessory IOF (AIOF) can result in incomplete anesthesia or treatment failure. Previous studies have demonstrated variable results regarding the prevalence of an AIOF ranging from 16.9% to 47.6%.

Objectives: The purpose of this study was to perform a morphological and morphometric study of the IOF and AIOF based on images of 3-dimensional (3D) facial bone computed tomography (CT) scans.

Study Design: Retrospective study.

Methods: Identification and analysis of patients who have undergone facial bone 3D CT were performed using Clinical Data Warehouse v 2.5 (CDW, Planit Healthcare, Seoul, Korea). The search term that we used with the CDW for analysis was "facial bone 3D CT."
First, the region below the infraorbital rim was examined to determine the presence of the IOF and AIOF. Second, the shape of the IOF was determined and categorized as circular or oval. Third, the vertical (VD) and horizontal (HD) diameters of the IOF were determined. Lastly, the distances between important anatomic landmarks and the IOF were measured.

Results: A single IOF with a circular shape was most common. The HD and VD of the IOF were significantly larger in men than in women. The distance between the IOF and the infraorbital margin was similar between men and women. The distances measured from the lateral nasal aperture (LNA) to the IOF and the anterior nasal spine (ANS) to the IOF, at both sides, were significantly shorter in women than in men. The prevalence of the AIOF on the right and left side was 7.3% and 8.9%, respectively. The most commonly observed position of the AIOF was on the inferior medial side of the IOF.

Limitations: This study had an imbalance in the number of male and female patients.

Conclusions: The size of the IOF was larger in men than in women. The distance of the IOF from the infraorbital margin was similar for men and women, whereas, the distances between the IOF and the ANS and the IOF and LNA were shorter in women than in men.

Key words: Accessory infraorbital foramen, diameter, facial bone CT, infraorbital foramen

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During the regional blockade of the face and maxillofacial surgery, the location of the infraorbital foramen (IOF) and its adjacent neurovascular structures are important considerations. Detailed knowledge of the anatomy of the area around the IOF is important to a successful nerve blockade and to avoid traumatic injury to the neurovascular structures during facial surgeries (1).

Previous results of variations in the IOF demonstrated conflicting results regarding to the side and gender. While some research has identified significant differences between the IOF and surrounding structures, other studies (1-3) have found no such differences. Varying results have also been reported concerning racial differences in IOF features. The measurement method used appears to be somewhat responsible for the inconsistent research findings (1,4).

The infraorbital nerve, which is the terminal branch of the trigeminal nerve, exits the maxilla via the IOF and provides sensory innervation to the lower eyelid, upper lip, and one side of the nose. Regional blockade of the infraorbital nerve is a common procedure used both for midface surgery and the treatment of trigeminal neuralgia. However, duplication of the infraorbital nerve due to the presence of an accessory IOF (AIOF) has been reported (5). The presence of an AIOF can result in incomplete anesthesia or treatment failure. The reported prevalence of an AIOF varies, ranging from 16.9% to 47.6% (5-7). Therefore, physicians should be cognizant of the possible presence of this AIOF nerve passing through an AIOF to ensure complete anesthesia and a successful neuralgia treatment outcome.

Recently, the 3-dimensional (3D) technology used in computed tomography (CT) scans has facilitated more reliable and accurate measurement of parameters, especially involving craniofacial structures (9). High reliability of measured parameters has been proven in previous studies (8,9). Intraobserver and interobserver variations defined on facial bone 3D CT were smaller compared with cephalograms. Since the 3D reformulation process makes possible easy and delicate comprehension of bony structures, more reliable and accurate measurement is possible (9,10).

The purpose of this study was to perform a morphological and morphometric study of the IOF and AIOF based on images of 3D facial bone CT scans.

Methods

Patients

This study was performed in a retrospective manner after approval of our institutional review board (2021-05-010). Patients who were evaluated with facial bone 3D CT following facial injury, between January 2020 and March 2021, were included. Since every patient had a prior history of facial trauma before CT scanning, all those diagnosed with an actual facial fracture were excluded. Also, patients who underwent previous surgery or manifested congenital anomalies in the orbit and mid-facial region were excluded in this study.

Identification and analysis of patients who have undergone facial bone 3D CT were performed using Clinical Data Warehouse v 2.5 (CDW, Planit Healthcare, Seoul, Korea) using the key words "facial bone 3D CT."

Measurements

All images were reconstructed 3-dimensionally using a 3D image reconstruction program (Picture Archiving and Communication System [PACS] M6, INFINITT Healthcare, Seoul, Korea). Each image slice was obtained at 3-mm thickness. Analysis and measurement of parameters were performed using images transmitted digitally via PACS.

One of authors (HJK), who had at least 3 years of experience in pain practice, performed the analysis and measurement of parameters. A radiologist (JHH) with more than 7 years of experience reviewed the axial and coronal scans to confirm the presence and location of an AIOF.

First, the region below the infraorbital rim was examined to determine the presence of the IOF and AIOF. If the IOF and AIOF were seen via 3D image, the axial and coronal scans were re-evaluated to confirm the location of the AIOF relative to the IOF (Figs. 1A~E). Second, the shape of the IOF was determined. The shape of the IOF was categorized as circular or oval (Figs. 2A and B). Third, the vertical (VD) and horizontal (HD) diameters of the IOF were determined (Fig. 3). Lastly, the distance from important anatomic landmarks to the IOF was measured. These included the vertical distance between upper margin of the IOF and the infraorbital rim, the horizontal distance between the medial margin of the IOF and the lateral margin of nasal aperture (LNA), and the horizontal distance between the medial margin of the IOF to the anterior nasal spine (ANS) (Figs. 4A, B, and C). The diameters and distances described above were measured using a length-measurement instrument installed in INFINITT PACS M6.

The trigeminal system was illustrated for an easy understanding (Fig. 5).

Medical records were carefully reviewed to obtain a detailed history of facial trauma and demographic characteristics.

Statistics

Values are presented as mean ([standard deviation] SD) or number of patients (%). A Student's t test was

used to compare the mean values between male and female patients and the right and left sides. All statistical values were 2-tailed, and *P* values < 0.05 were considered statistically significant. Statistical evaluations were performed using SPSS v 22.0 (IBM Corporation, Armonk, NY, United States).

Results

The right and left sides of hemiface in 191 patients using 3D facial bone CT were analyzed.

The 191 patients included 139 male patients (72.8%). The mean age of male and female patients was 52.7 years and 52.9 years, respectively.

The shape of the IOF demonstrated circular or oval shape. A single IOF with a circular shape was most common among them. There were no significant differences between different genders and sides (Table 1).

The HDs of the right and left IOF averaged 3.4 mm and 3.2 mm, respectively. The HDs of the left IOF were significantly larger in men than in women (*P* < 0.01, Table 2). The VDs of the right and left IOF averaged 3.1 mm and 3.0 mm, respectively. The VDs of both sides of the IOF were significantly larger in men than in women (*P* < 0.01, Table 2).

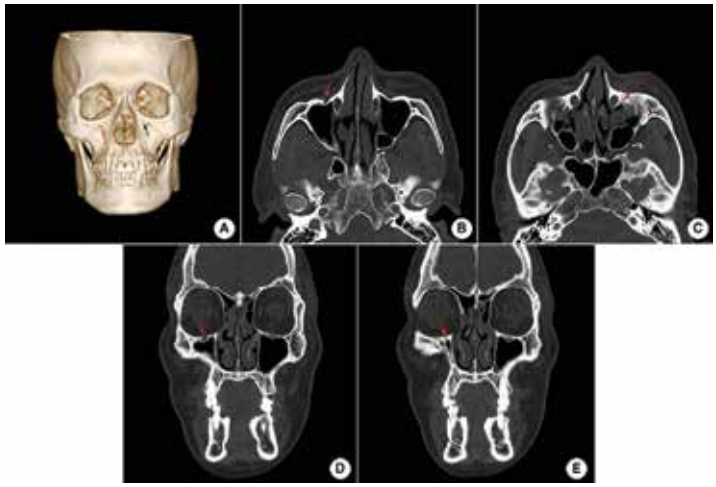

Fig. 1. (A) *The red and black arrows indicate the IOF and AIOF, respectively.* (B) *The red arrow on axial CT scans shows the passage of the IOF.* (C) *The red arrow on axial CT scans shows the passage of the AIOF.* (D) *The red arrow on coronal CT scans shows the passage of the IOF.* (E) *The red arrow on coronal CT scans shows the passage of the AIOF.*
IOF, infraorbital foramen; AIOF, accessory infraorbital foramen; CT, computed tomography.

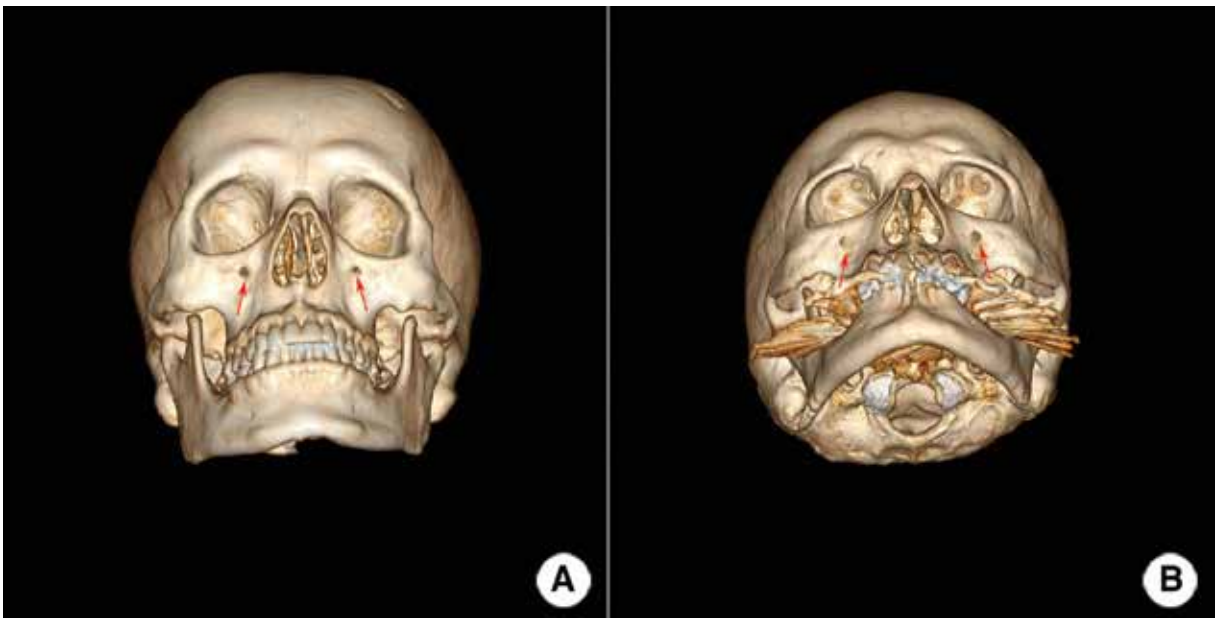

Fig. 2. *The red arrow indicates circular* (A) *or oval* (B) *shape of the IOF.*
IOF, infraorbital foramen.

Fig. 3. *Measurement of the VD and HD of the IOF. VD, vertical diameter; HD, horizontal diameter; IOF, infraorbital foramen.*

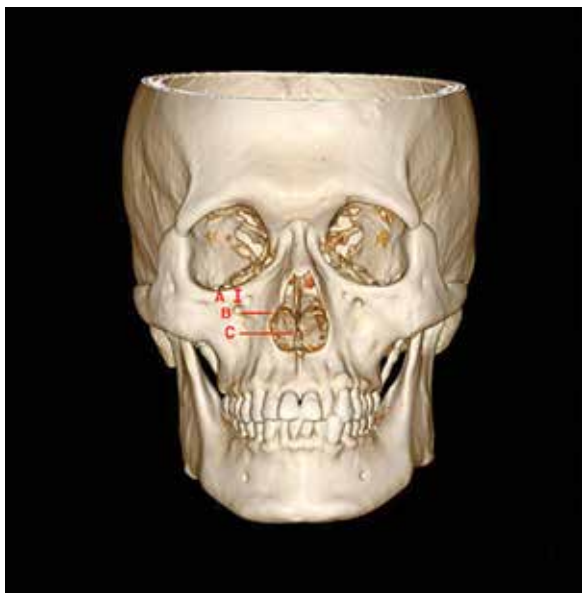

Fig. 4. A, B, and C *show the distances between the infraorbital margin and the IOF, the LNA and the IOF, and the ANS and the IOF, respectively. IOF, infraorbital foramen; LNA, lateral nasal aperture; ANS, anterior nasal spine.*

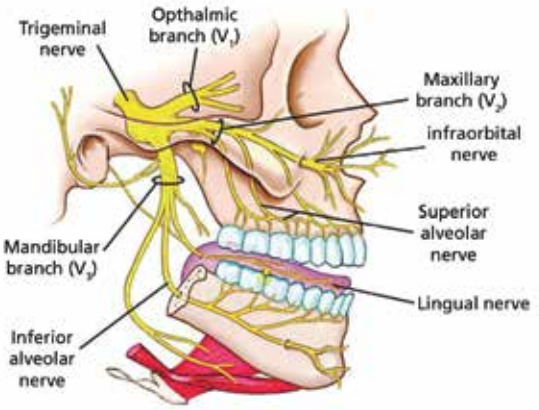

Fig. 5. *Illustration showing the trigeminal system.*

The distance between the orbital inferior margin (OIM) and the IOF was 8.2 mm on both sides. There were no significant differences between men and women. The mean distances between the LNA to the IOF on the right and left sides were 15.1 mm and 14.9 mm, respectively. These distances between the LNA and the IOF on both sides of the face were significantly greater in men than in women ($P < 0.01$, Table 3). The mean distances between the ANS to the IOF on the right and left sides were 25.8 mm and 26.2 mm, respectively. These distances between the ANS and the IOF on both sides of the face were significantly greater in men than in women ($P < 0.01$, Table 3).

The prevalence of an AIOF on the right and left sides of the face was 7.3% and 8.9%, respectively. The most common position of an AIOF was the inferior medial side of the IOF (Table 4).

Discussion

Our study showed significant differences in the size of the IOF and distances from important anatomical landmarks between genders. The HD of the left IOF was significantly larger in men than in women. Also, the VD of the IOF on both sides of facial hemispheres was significantly larger in men than in women. Overall, this study demonstrated that the IOF is larger in men than in women. Although we found no significant differences between the sizes of the right and left IOF, a previous study (6) demonstrated a significantly larger transverse diameter in the left IOF than the right side.

In this study, a circular shape of the IOF was found most commonly followed by an oval shape. We found none of a semilunar shape despite a previous study (6) having found the IOF to be a circular, oval, or semi-

lunar shape. On the other hand, when Indian skulls were studied (4), an oval shape of the IOF was most predominant followed by a circular shape (11). It seems that facial bone foramen shows variability according to the race or population evaluated. For surgeons and pain physicians to perform precise needle insertion, detailed knowledge of the morphology of the IOF is essential (7).

In the present study, the distance of the IOF from important anatomical landmarks was measured to more accurately determine the location of the IOF. In this study, we used the facial midline (ANS) as a reference landmark. The mean distance between the infraorbital margin and the IOF was found to be 8.2 mm on both sides of the face. There was no significant differences between genders and facial hemispheres. When this analysis was performed on Brazilian skulls, it showed average values of 6.35 mm and 6.57 mm on the right and left sides, respectively (6). A study of North American cadavers (3) showed 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. A study of Asian skulls (1) showed 7.8 mm and 8.0 mm for the right and left sides, respectively. Like us, the latter study did not find significant differences between genders in the distances between the infraorbital margin and the IOF. It seems that more variability exists between different races than genders in this parameter.

The mean distances between the IOF and the ANS of men were 26.3 mm and 26.5 mm on the right and left facial hemispheres, respectively. These mean distances were significantly shorter on both sides in women. Previous research (1) found that the location of the IOF in women is more central than it is in men.

The presence of an AIOF nerve passing through an AIOF can be related to incomplete anesthesia or treatment failure. Moreover, the prevalence and exact location of these accessory foramina are connected to the potential risk of the iatrogenic injury during facial surgery. Therefore, it is essential to evaluate the prevalence and anatomical characteristics of an AIOF. This study revealed a prevalence of 7.3% and 8.9% on the right and left sides of the face, respectively. The results of prevalence of an AIOF show variability ranging from 16.9% to 47.6% (5-7). Such variability results from differences between populations, races, and genders (12). Moreover, the prevalence of an AIOF in this study was evaluated indirectly using images of 3D facial bone CT. Since the diameter of an AIOF is known to be less than 2 mm (13), confirming the existence of an AIOF can be

Table 1. *Shape of the IOF.*

	Men (n = 139)		Women (n = 52)		Tota (n = 191)	
	Right	Left	Right	Left	Right	Left
Circular	91 (65.4)	94 (67.6)	41 (78.8)	42 (80.7)	139 (72.7)	136 (71.2)
Oval	48 (34.5)	45 (32.3)	11 (21.1)	10 (19.2)	52 (27.2)	55 (28.7)

Abbreviation: IOF, infraorbital foramen.
Values are number (%).

Table 2. *HD and VD of the IOF.*

	Men (n = 139)		Women (n = 52)		Total (n = 191)	
	Right	Left	Right	Left	Right	Left
HD (mm)	3.4 (0.8)	3.4 (0.8)	3.2 (0.7)	2.8 (0.8)*	3.4 (0.8)	3.2 (0.9)
VD (mm)	3.2 (0.6)	3.1 (0.5)	2.9 (0.5)*	2.8 (0.5)*	3.1 (0.6)	3.0 (0.6)

*$P < 0.01$ (men vs women)
Values are mean (SD).
Abbreviations: HD, horizontal diameter; VD, vertical diameter; IOF, infraorbital foramen.

Table 3. *Distances from the IOF to anatomical landmarks.*

	Men (n = 139)		Women (n = 52)		Total (n = 191)	
	Right	Left	Right	Left	Right	Left
IOF ~ OIM (mm)	8.2 (1.6)	8.2 (1.7)	8.2 (1.8)	8.5 (2.6)	8.2 (2.0)	8.2 (1.8)
IOF ~ LNA (mm)	15.5 (2.1)	15.3 (2.2)	13.9 (1.9)*	14.1 (1.7)*	15.1 (2.2)	14.9 (2.1)
IOF ~ ANS (mm)	26.3 (2.3)	26.5 (2.1)	24.7 (2.6)*	25.4 (1.7)*	25.8 (2.5)	26.2 (2.1)

*$P < 0.01$ (men vs women)
Values are mean (SD).
Abbreviations: IOF, infraorbital foramen; OIM, orbital inferior margin; LNA, lateral margin of nasal aperture; ANS, anterior nasal spine.

Table 4. *Prevalence and position of AIOF, on the right and left side of the skull.*

	AIOF	
	Right n (%)	Left n (%)
Prevalence	14 (7.3)	17 (8.9)
Superior and Medial	6 (42.8)	7 (41.1)
Inferior and Medial	8 (57.1)	10 (58.8)

Abbreviation: AIOF, accessory infraorbital foramen.

missed due to its small size. Therefore, there can be some discrepancies between our results and previous results of an AIOF prevalence using dry skulls or cadavers. When the prevalence of an AIOF was compared between the right and left sides, most AIOFs were located on the left side of the skulls (6,7). On the other hand, other studies (5,14) demonstrated similar distribution of an AIOF between the right and left sides of the skull. The present study also showed slightly higher prevalence of an AIOF on the left than right side, however, such difference did not demonstrate any statistical significance. The circular shape of the AIOF was most predominant on both sides of the skulls (6,14).

Most of the previous studies (5-7,14) demonstrated the location of an AIOF on the superior medial side of the IOF as the most common location. However, this study revealed the location of an AIOF on the inferior medial side of the IOF most commonly followed by the superior medial side.

Limitations

This study includes several limitations. First, all evaluations were performed based on images of 3D CT scans. Therefore, direct comparisons with the measurements of previous studies taken from cadavers or dry skulls might lead to some inaccuracies or differences. Second, this study had a gender imbalance in the study sample, with around three-quarters of the patients being men. Such an imbalance in the number might have some impacts on the measurement of the IOF from the anatomical landmark.

Conclusion

The shape of the IOF was predominantly circular. The size of the IOF was larger in men than in women. The distances of the IOF from the infraorbital margin were similar in men and women, whereas the distances of the IOF from the ANS and the LNA were shorter in women than in men.

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