Anatomical Location of the Infraorbital Foramen in Thai Patients: A Retrospective Cone-beam Computed Tomography Evaluation

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Abstract

Accurate localization of the infraorbital foramen (IOF) is vital for effectively administering infraorbital nerve blocks and minimizing the risk of infraorbital nerve injury during operations. Comprehending anatomical variations in this region is also essential for forensic identification and cosmetic procedures. This study aimed to determine the distance between the IOF and surrounding anatomical structures using cone-beam computed tomography (CBCT). A retrospective analysis was conducted using CBCT scans from 375 patients (123 males, 252 females) aged 18 to 62 to assess the linear distances between the IOF and adjacent anatomical structures. Statistical analyses were performed using independent t-tests, with statistical significance set at $p < 0.05$. Male subjects exhibited significantly greater measurements than females on both sides. The total mean distance from the IOF to the adjacent structures on the right and left sides was as follows: infraorbital rim, 8.96±1.92 mm, and 8.87±1.85 mm; pyriform aperture, 18.05±2.72 mm, and 18.14±2.7 mm; facial midline, 25.48±2.20 mm, and 25.44±2.19 mm; and maxillary alveolar margin, 31.23±3.39 mm, and 30.88±3.28 mm, respectively. No statistically significant differences were found between the two sides, except for the distance between the IOF and the maxillary alveolar margin. The relative position of the IOF varies among populations. These findings may assist in the precise administration of infraorbital nerve blocks, reduce nerve injury risks during maxillofacial surgeries, and support sex estimation in the forensic field. Furthermore, these measurements hold value for maxillofacial surgeons, forensic scientists, and anesthesiologists.

Keywords: *infraorbital foramen, infraorbital nerve block, cone-beam computed tomography*

1. Introduction

The infraorbital foramen (IOF) is an aperture located in the maxillary bone beneath the infraorbital margin of the orbit, through which the infraorbital vessels and nerve fibers emerge (Ali et al., 2018). The infraorbital nerve, a terminal branch of the maxillary division of the trigeminal nerve, travels along the orbital floor within the infraorbital groove and eventually exits the orbit through the infraorbital foramen, providing sensory innervation to the lower eyelid, lateral aspect of the nose, upper lip, upper incisors, canines, premolars, the root of the first molar, and the associated gingiva (Aggarwal et al., 2015). The IOF holds significant relevance in maxillofacial surgical procedures and forensic anthropology. Recent studies have emphasized the clinical and surgical relevance of precise IOF localization using cone-beam computed tomography (CBCT), particularly for regional anesthesia and reconstructive procedures. Moreover, CBCT provides a three-dimensional visualization, thereby enhancing the accuracy of anatomical assessments compared to conventional methods (Razak, Narayanan, & Gurram, 2024). Temporary or permanent facial hypoesthesia, paranesthesia, or neuralgia may arise due to iatrogenic injury to the infraorbital nerve. Such injury may comprise avulsion, or partial or complete disruption of the nerve. The infraorbital nerve is particularly vulnerable during a Caldwell-Luc procedure when the facial flap is elevated at the infraorbital foramen, or during an expanded endoscopic approach involving removal of the posterior wall of the maxillary sinus to access the infra-temporal fossa. Postoperative facial numbness has been reported in 2% to 9% of patients undergoing Caldwell-Luc procedures, and in 44% to 67% of those receiving endoscopic pterygopalatine fossa surgery (Ference et al., 2015).

The infraorbital nerve block is among the most common types of regional anesthesia in oral and maxillofacial surgery. It is administered by injecting an anesthetic agent into the region of the infraorbital nerve. This procedure can be performed via either an intraoral or extraoral approach. The intraoral approach involves injecting an anesthetic solution into the buccal mucosa adjacent to the maxillary second premolar. The inferior orbital rim serves as the primary anatomical landmark, identified using the middle fingers of the non-injecting hand. Once the inferior orbital rim is located, the palpating finger should remain in place to maintain the landmark and prevent the needle from penetrating the orbit. The needle is advanced superiorly toward the infraorbital foramen, remaining parallel to the second bicuspid, until it is palpated in proximity to the infraorbital foramen. For the extraoral approach, the IOF can be located by asking the patient to look straight ahead. An imaginary line descending from the pupil to the inferior border of the infraorbital rim through the bicuspid teeth, and the mental foramen is used as a reference point. The needle is inserted through the skin, subcutaneous tissue, and muscle. The extraoral approach involves the administration of anesthetic into the tissues surrounding the infraorbital foramen (Nardi & Schaefer, 2020). Therefore, accurate localization of the IOF is crucial for the effective delivery of the infraorbital nerve block and the prevention of nerve injury during facial operations, including facial fracture surgery and cosmetic operations (Ismail & Al-Refai, 2016).

2. Objectives

To examine the anatomical variations of the IOF and its surrounding structures via morphometric measurements using CBCT.

3. Materials and Methods

A retrospective study was conducted to evaluate the location of the infraorbital foramen and its relationship to gender and side, using 375 CBCT scans of Thai subjects (123 males and 252 females), with ages ranging from 18 to 62 years. The study was carried out at the Oral and Maxillofacial Radiology Clinic, Dental Hospital, Faculty of Dentistry, Mahidol University. This study received ethical approval from the Research Ethics Committee and the Institutional Review Board of the Faculty of Dentistry and the Faculty of Pharmacy, Mahidol University (MU-DT,/PY-IRB 2021/031.2603).

All subjects were patients who underwent CBCT evaluation for orthognathic surgery between 2018 and 2020. CBCT images were obtained using the Kodak CS9500 (Carestream, New York, NY, USA) with the following parameters: 90 kV, 10 mA, 10.8 seconds exposure time, and 20.6 x 18 cm field of view, with an isotropic voxel size of 0.3 mm. Only CBCT images covering the region of interest, which extended from the infraorbital rim to the upper teeth, were included in the study. Exclusion criteria comprised patients who had undergone prior mid-facial or maxillofacial surgery, had growth-affecting conditions such as hyperparathyroidism, congenital anomalies/syndromes affecting the head and neck (e.g., Turner syndrome), maxillary pathological cysts or tumors, extensive upper teeth loss, or inadequate CBCT images (e.g., blurring or severe metallic artifacts in the midfacial region).

A post-graduate dental student with four years of experience performed all evaluations (ST). All measurements were conducted using CS 3D imaging software (Carestream, New York, NY, USA) and the linear measurement function. The distances from IOF to surrounding structures were recorded in millimeters. The reference plane was first established based on the Frankfort horizontal plane. Linear distances measuring from the infraorbital foramen to adjacent anatomical structures, including the infraorbital rim, pyriform aperture, facial midline, and maxillary alveolar margin, were evaluated on the same monitor under dim lighting. Prior to the experiment, 20% of the cases were calibrated by an oral and maxillofacial radiologist with ten years of experience (SN) using the same monitor.

The following anatomical measurements were assessed:

A. The vertical distance between the superior border of the IOF and the infraorbital rim (IOR) on the sagittal view (Figure 1a).

B. The transverse distance between the medial border of the IOF and the pyriform aperture (PA) on the axial view (Figure 1b).

C. The transverse distance between the medial border of the IOF and the facial midline on the coronal view (Figure 1c).

D. The vertical distance between the inferior border of the IOF and the maxillary alveolar margin on the coronal view (Figure 1c).

Figure 1 Linear distance measurement from IOF to IOR (a.), PA (b.), facial midline, and maxillary alveolar margin (c.)

Statistical analysis was performed by reporting linear distances from the infraorbital foramen (IOF) to adjacent anatomical structures using means and standard deviations. Differences based on gender and side were assessed using independent t-tests and paired t-tests, respectively. Inter-rater reliability was determined using intraclass correlation coefficients in SPSS® version 18.0 (IBM Corp., NY, USA), with statistical significance set at $p < 0.05$.

4. Results and Discussion

4.1 Results

The study included a total of 375 subjects, comprising 123 males and 252 females, aged between 18 and 62 years, with a mean age of 27.38 ± 6.50 years. In all analyzed cases, the infraorbital foramen (IOF) was observed bilaterally. Regarding the vertical distance from the superior border of the IOF to the infraorbital rim (IOR), the mean distances were 8.96 ± 1.92 mm on the right side and 8.87 ± 1.85 mm on the left side, with no statistically significant side difference (P = 0.107). However, significant gender-based differences were observed, with males exhibiting greater distances than females on both sides (P = 0.008 on the right side; P = 0.002 on the left).

The mean distance between the medial border of IOF and the pyriform aperture (PA) was 18.05 ± 2.72 mm on the right side and 18.14 ± 2.72 mm on the left side, with no statistically significant side difference (P = 0.379). Males displayed significantly greater distances than females on both sides (P < 0.001). In terms of the distance between the medial border of IOF and the facial midline, the mean values were 25.48 ± 2.20 mm and 25.44 ± 2.19 mm on the right and left sides, respectively, with no statistically significant difference between the two sides (P = 0.650). However, males exhibited significantly greater distances than females on both sides (P < 0.001).

The distance between the inferior border of IOF and the maxillary alveolar margin was greater on the right side (31.23 ± 3.39 mm) than on the left side (30.88 ± 3.28 mm), with a statistically significant side difference (P = 0.001). Males displayed significantly greater distances compared to females on both sides (P < 0.001). Comparisons of the distances between the IOF and adjacent anatomical structures, by sides and gender, are presented in Table 1 and Table 2, respectively. Inter-rater reliability for linear measurements between the IOF and adjacent structures was classified as good to excellent (ICC = 0.738 – 0.925).

Table 1 Comparing the distance between an infraorbital foramen and adjacent anatomical structures between sides

	Right (mm)	Left (mm)	Mean difference (95%CI)	P-value
Distance from superior border of the IOF to the IOR	8.96 ± 1.92	8.87 ± 1.85	0.09 (-0.02, 0.21)	0.107
Distance from medial border of the IOF to the PA	18.05 ± 2.72	18.14 ± 2.72	-0.09 (-0.31, 0.12)	0.379
Distance from medial border of the IOF to the facial midline	25.48 ± 2.20	25.44 ± 2.19	0.04 (-0.14, 0.22)	0.650
Distance from inferior border of the IOF to the maxillary alveolar margin	31.23 ± 3.39	30.88 ± 3.28	0.35 (0.15, 0.55)	0.001*

Data were presented by mean ± SD and analyzed with a Paired t-test, CI = Confidence Interval
* Statistically significant at the 0.05 level

Table 2 Comparing the distance between an infraorbital foramen and adjacent anatomical structures between genders

Distance	Male (mm)	Female (mm)	Mean difference (95%CI)	P-value
From superior border infraorbital foramen to infraorbital rim				
Right	9.34±1.97	8.78±1.88	0.56 (0.15, 0.98)	0.008*
Left	9.30±1.92	8.66±1.77	0.64 (0.25, 1.04)	0.002*
From medial border infraorbital foramen to pyriform aperture				
Right	19.66 ± 2.76	17.26±2.32	2.41 (1.87, 2.94)	<0.001*
Left	19.62 ± 2.79	17.42±2.37	2.20 (1.62, 2.78)	<0.001*
From medial infraorbital foramen to facial midline				
Right	26.53±2.31	24.97±1.95	1.56 (1.11, 2.01)	<0.001*
Left	26.30±2.31	25.02±2.00	1.28 (0.83, 1.74)	<0.001*
From inferior border infraorbital foramen to maxillary alveolar margin				
Right	33.45±3.36	30.15±2.83	3.30 (2.65, 3.95)	<0.001*
Left	32.99±3.04	29.84±2.87	3.16 (2.52, 3.79)	<0.001*

Data were presented by mean ± SD and analyzed with an independent t-test, CI = Confidence Interval
* Statistically significant at the 0.05 level

4.2 Discussion

CBCT has become a widely used imaging modality for the oral and maxillofacial region due to its three-dimensional display structure, high spatial resolution, and lower radiation dose than medical CT. This makes CBCT superior to conventional radiographic techniques. Furthermore, CBCT offers significant benefits over direct measurements (White & Pharoah, 2018).

The anatomical features of the foramina in the facial region are of significant importance in facial surgical procedures. The IOF is an essential structure within the maxillary bone, through which the infraorbital vessels and nerve fibers pass (Ali et al., 2018). Substantial evidence has demonstrated variations in the relative position of IOF across different populations. Therefore, accurately locating the IOF is crucial for providing infraorbital nerve block effectively and preventing injury to the infraorbital nerve during facial fracture surgery and cosmetic operations (Ismail & Al-Refai, 2016).

The present study observed that the total mean distance from IOF to the IOR was greater than the measurements observed in India, Caucasoid, and USA human dry skulls, where the distances ranged from 6.12 ± 1.79 mm to 7.65 ± 1.35 mm on the right side and 6.19 ± 1.81 mm to 7.11 ± 1.73 mm on the left side (Aggarwal et al., 2015; Bharti, & Puranik, 2013; Boopathi et al., 2010; Saini, 2014; Singh, 2011; Vershney, & Sharma, 2013; Gibelli et al., 2019; Mecedo, Cabrini, & Faig-Leite, 2009; Masabni, & Ahmad, 2017; Polo et al., 2019; Zhang et al, 2019). Our study showed slightly greater measurements compared to those conducted in Kurdish, Turkish, and Lebanese populations using CBCT, with distances ranging from 7.43±1.87 mm to 7.94±1.45 mm on the right side and 7.39±1.41mm to 8.03±1.37mm on the left side (Ismail & Al-Refai, 2016; Bahşi et al., 2019; Orhan et al, 2016; Sokhn et al., 2019). No statistically significant difference was found between the two sides in our study, which aligns with most previous studies, whether conducted on human dry skulls, cadavers, or by using CBCT, which showed no significant difference between the two sides (Aggarwal et al., 2015; Ismail, & Al-Refai, 2016; Boopathi et al., 2010, Saini, 2014; Singh, 2011; Gibelli et al., 2019; Masabni, & Ahmad, 2017; Polo et al., 2019; Zhang et al., 2019; Bahsi et al, 2019; Orhan et al, 2016; Agthong, Huanmanop, & Chentanez, 2005; Aziz, Marchena, & Puran, 2000). However, when comparing genders, our study showed that the mean distances on both sides in males were significantly greater than those in females, consistent with the findings by Aphinasmit et al. (2006) on Thai human dry skulls and a study by Ismail and Al-Refai (2016) conducted using CBCT showing the greater distance in males over females. The IOR serves as an anatomical landmark for infraorbital nerve block in both intraoral and extraoral approaches. Complications from infraorbital nerve blocks may include bleeding, hematoma formation, infection, injury to the artery or vein, unintentional injection of anesthetic into the artery or vein, nerve damage, or edema. Moreover, injection into the IOF could lead to long-term neuropathy due to nerve compression, orbital floor damage, or injury to the orbit (Kane et al., 2015; Wang et al., 2015). Our study supports the significant gender difference in the distance from IOR to IOF, indicating that a more precise localization of the IOF may reduce complications. This finding highlights the benefit of avoiding complications during the infraorbital nerve block procedure.

The mean distance between IOF and PA in the present study revealed no statistically significant difference between the two sides. This finding is consistent with the majority of previous investigations using both human dry skulls and CBCT, which also reported no side-related variations. However, the distances observed in our study were greater than those reported in prior studies conducted on dry skulls from India, Brazil, and the USA, as well as in a CBCT-based study on the Kurdish population. Those studies reported IOF-PA distances ranging from 15.31 ± 1.77 mm to 17.75 ± 2.10 mm on the right and from 14.87 ± 1.73 mm to 17.97 ± 2.46 mm on the left side (Aggarwal et al., 2015; Ismail, & Al-Refai, 2016; Bharti, & Puranik, 2013; Saini, 2014; Singh, 2011; Varshney and Sharma, 2013; Mecedo, Cabrini, & Faig-Leite, 2009; Polo et al., 2019). Furthermore, our findings demonstrated that the linear distances from IOF to PA were significantly greater in males than in females on both sides. This observation aligns with a result reported by Ismail and Al-Refai (2016), who also found a significant gender-based difference.

Aggrwal et al. (2015) investigated the linear distance between IOF and the facial midline using Indian dry skulls, reporting a mean distance of 25.63 ± 2.27 mm on the right side and 25.63 ± 2.50 mm on the left, findings that are consistent with those of the present study. Numerous earlier investigations—whether based on dry skulls, cadaveric specimens, or CBCT—similarly reported no significant differences between sides across diverse populations. Regarding gender, however, our study demonstrated significantly greater distances in males compared to females. This agrees with the study from Aphinasmit et al. (2006), who conducted a study on Thai dry skulls. Correspondingly, Sokhn et al. (2019) also reported gender-related differences in a CBCT-based study on the Lebanese population.

In the present study, the vertical distance between the inferior border of IOF and the maxillary alveolar margin showed greater measurement on the right side, contradicting many previous studies reporting no differences between sides. Our study demonstrated a greater measurement than those reported in earlier research, which indicated that the mean distance was 28.38 - 30.56 mm on the right side and 28.42 - 30.11 mm on the left (Aggarwal et al., 2015; Bharti, & Puranik, 2013; Masabni, & Ahmad, 2017; Polo et al., 2019). These variations might be attributed to the periodontal status, which may influence the distance from the IOF to the alveolar margin. Moreover, some patients may present with slight maxillary canting. Thus, clinicians using this anatomical landmark should be aware.

In the present study, all the linear measurements between IOF and anatomical structures in males were significantly greater than in females on both the right and left sides. We evaluated the distances from the IOF to adjacent anatomical structures and compared them between sides and gender. Moreover, the observations from this study may be useful in determining the gender of corpses in the forensic field. This is because the surgical procedures related to sex reassignment in the facial region are generally limited to cheekbones and jaw surgeries, and these procedures do not alter the position of the IOF. Therefore, the location of the IOF may serve as a reliable indicator in determining the deceased's original gender.

The limitations of the present study were that, since the subjects' heights were not documented, it was not possible to compare gender-related measurements concerning height. In addition, the inclusion of 18-year-old subjects, who may still be undergoing skeletal growth, presents a potential limitation in interpreting the findings.

5. Conclusion

The distance between the location of the IOF and surrounding anatomical structures demonstrates anatomical variations and gender-related differences. Males tend to exhibit greater distances than females. These findings could aid in successfully establishing an infraorbital nerve block, preventing nerve injury during surgery in the maxillofacial region, and determining the sex of corpses in the forensic field.

Conflicts of interest

None of the authors has any financial interests related to this study to disclose.

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