

Morphometric evaluation of the infraorbital foramen in human dry skulls of South Indian population

Bhagath Kumar Potu^{1*}, Gowtham Chandra Srungavarapu², Thejodhar Pulakunta³

¹Department of Anatomy, College of Medicine and Medical Sciences, Arabian Gulf University, Bahrain

²Department of Oral and Maxillofacial surgery, Dental College and Hospital, RGUHS, India

³Department of Medical Neuroscience, Faculty of Medicine, Dalhousie University, Halifax, Nova Scotia, Canada

Abstract

The aim of this study was to determine the location of the infraorbital foramen (IOF) in relation to infraorbital margin (IOM), anterior nasal spine (ANS) and Nasion (NA), Supraorbital margin (SOM) and sockets of the maxillary teeth in adult skulls (of South Indian population). Fourteen skulls (28 sides) have been analyzed. In order to analyse the size and the relative position of the IOF with the above parameters, we have used a digital caliper for measurements with a precision of 0.01 mm. The IOF was oval in shape (85.7 %) on right side and (71.4 %) on left side while none of them were found either in semilunar or triangular shape in contrast to previous reports. In most of the cases IOF was found to be situated lateral to the plane of SOM. The vertical and transverse diameter of the IOF on both sides was found to be almost equal. The mean distance and standard deviation (mean \pm SD) between right IOF and ANS, IOM and NA were 33.6 ± 2.22 mm, 5.49 ± 1.10 mm and 41.4 ± 3.27 mm respectively, while the mean \pm SD between left IOF and ANS, IOM and NA were 33.1 ± 2.30 mm, 5.85 ± 1.06 mm and 40.3 ± 3.09 mm respectively. The results obtained from descriptive analysis are relevant and help surgeons for blocking the infraorbital nerve while performing surgeries in midface region, particularly in patients with edema of the infraorbital region when precise location of the IOF is difficult.

Keywords

Infraorbital foramen, infraorbital margin, size, distance, measurements.

Introduction

Infraorbital region, particularly the infraorbital foramen is an important site for various surgical and anesthetic procedures. The infraorbital nerve, which is the continuation of the second (maxillary) division of the trigeminal nerve passes through it and is responsible for the sensory innervation of the lower eyelid, nasal ala, upper lip, the anterior, premolar teeth and associated gingiva (Standring, 2008). The classical location of the infraorbital foramen (IOF) is seen on the external anterior surface of the maxilla below the infraorbital margin. Precise localization of the foramen is the key to success in blocking this nerve and this can be challenging due to its anatomical variation in its shape and size (Zide & Swift, 1998). We have undertaken this study to determine a more precise location of the IOF in relation to the infraorbital margin (IOM), nasion (NA) and anterior nasal spine (ANS) and also to measure its

* Corresponding author. E-mail: potubk@agu.edu.bh

shape, location with reference to the plane of supraorbital margin (SOM), molar and premolar teeth respectively to derive an accurate reference point to locate the IOF and its structures in clinical situations such as surgery and anesthetic procedures. Multiple studies have been attempted to determine the position of IOF with nearby landmarks and have shown to vary among population groups. And standard text books show that the IOF is located approximately 1 cm inferior to the IOM. However, various studies reported that this range may vary between 6-12mm respectively (Hindy & Abdel-Raouf, 1993; Chung *et al.*, 1995; Canan *et al.*, 1999; Aziz *et al.*, 2000; Kazkayasi *et al.*, 2001; Karakas *et al.*, 2002; Elias *et al.*, 2004; Agthong *et al.*, 2005; Apinhasmit *et al.*, 2006; Gupta, 2008; Lopes *et al.*, 2009; Macedo *et al.*, 2009; Ilayperuma *et al.*, 2010; Boopathi *et al.*, 2010; Singh, 2011; Lokanayaki, 2013; Elsheikh *et al.*, 2013; Ukoha *et al.*, 2014; Aggarwal *et al.*, 2015; Veeramuthu *et al.*, 2016; Cisneiros de Oliveira *et al.*, 2016; Nanayakkara *et al.*, 2016; Masabni & Ahmad, 2017). Although few studies were conducted on human dry skulls of Indian region using a different set of landmarks, the information available on the dimensions and relative position of the IOF from various points of reference in the South Indian population is scarce. Thus, for an accurate surgical practice, it is very important to have knowledge of the topographical anatomy of the IOF. Hence, the present study was undertaken on the dry human skulls of southern part of India considering all the important landmarks around IOF. A comprehensive review of literature has also been conducted in this study.

Materials and Methods

This study was carried out on 14 dry skulls obtained from Farooqia Dental College & Hospital in southern India. The skulls were measured on both sides (right and left) totaling 28 sides. The sex and age of the skulls were unknown. Deformed skulls were excluded from the study. The study has been approved by the ethical committee of Farooqia Dental College & Hospital, Mysore (number: FDC/ MDS/09/2018-19).

The skulls were first placed in the anatomical position and then examined for the shape; presence of accessory foramina and the direction of the IOF. These were recorded in a tabular column before taking the measurements. Superior margin of IOF was the main reference point from which all the measurements were recorded with a digital caliper (Japan, 0.01 mm precision). The following parameters were measured on the right and left sides parallel to sagittal plane and perpendicular to Frankfurt plane.

- The vertical diameter of the IOF
- The horizontal diameter of the IOF
- The distance between the IOF and ANS (A) (Figures. 1A,B)
- The distance between the IOF and the nasion (B) (Figures. 1A,B)
- The vertical distance between the IOF and IOM (C) (Figures. 1A,B)
- The relative position of the IOF with regards to the socket of maxillary teeth (D) (Figure 1)
- The relative position of the IOF in relation to the SOM (E) (Figures. 1A,B)

The distance from the most superior border of IOF to the upper margin of the sockets of the first molar, first premolar and second premolar was measured along with the vertical axis (D). The above measurements were repeated three times to

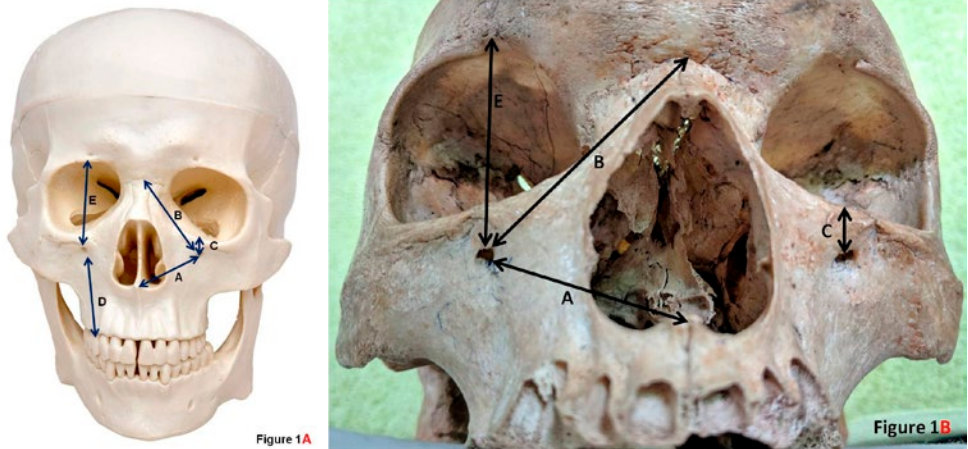


Figure 1. Showing the measurements conducted on the skulls. The distance between the IOF and ANS (A). The distance between the IOF and the nasion (B) (Figure 1A & 1B); The vertical distance between the IOF and IOM (C) (Figure 1A & 1B); The relative position of the IOF with regards to the maxillary teeth (D) (Figure 1); The relative position of the IOF in relation to the SOM (E) (Figure 1A & 1B).



Figure 2. Showing the different shapes of the IOF found in the study. 2A: Oval shaped IOF; 2B: Circular shaped IOF.

avoid procedural error/bias. The mean, range, and standard deviation of all the measurements were statistically analyzed. (Figure 1A is presented from the skull model to show the landmarks clearly and Figure 1B is one of the skulls we used in the study).

Results

All skulls studied have presented an IOF on both sides. The most frequent shape of the IOF was oval (Figure 2A) (85.7% on the right side and 71.4% on the left side) followed by circular (Figure 2B) (14.2% on the right side and 28.5% on the left side) while no semilunar and triangular outlined IOF's were found (Table 1) (Figure 2). The vertical and horizontal diameters of the IOF and distance its from ANS, IOM and NA are shown in Table 2 (left side) and Table 3(right side). The differences between left and right sides were not statistically significant.

With regards to the position of IOF to SOM (Table 4), it is evident that the majority of the IOF were located lateral to SOM (57.1% on left side and 50% on right side) and medial to SOM (21.4% on left side and 14.2% on right side). The incidence of IOF

Table 1. Shape of the IOF on the right and left sides in %. IOF: infraorbital foramen.

Shape	Right (%)	Left (%)	Accessory IOF (%)	
			Right	Left
Ovoid	85.7	71.4	14.2%	14.2%
Circular	14.2	28.5	-	-
Semilunar	0	0	-	-
Triangular	0	0	-	-

Table 2. Measurements of the IOF on left side. IOF: infraorbital foramen, IOM: infraorbital margin, ANS: anterior nasal spine,NA: nasion.

Measurement(mm)	Minimum	Maximum	Mean ± SD
Vertical diameter	2.08	5.39	3.82± 0.83
Transverse diameter	2.11	6.91	3.86± 1.54
Distance from IOF to ANS	29.18	35.92	33.13± 2.30
Distance from IOF to IOM	4.51	8.56	5.85 ±1.06
Distance from IOF to NA	34.52	46.95	40.39 ±3.09

Table 3. Measurements of the IOF on right side. IOF: infraorbital foramen, IOM: infraorbital margin, ANS: anterior nasal spine,NA: nasion.

Measurement (mm)	Minimum	Maximum	Mean ± SD
Vertical diameter	2.23	5.02	3.95 ±0.86
Transverse diameter	0.98	5.54	3.70± 1.20
Distance from IOF to ANS	28.47	37.99	33.62 ±2.22
Distance from IOF to IOM	3.29	7.59	5.49±1.10
Distance from IOF to NA	34.07	47.10	41.45 ±3.27

Table 4. Positioning of the IOF in relation with SOM and maxillary teeth.SOM: supraorbital margin.

Position	Right	Left
Along with same plane of SOM	35.7%	21.4%
Medial to SOM	14.2%	21.4%
Lateral to SOM	50%	57.1%
With regards to teeth		
In line with 1 st molar	14.2%	0%
In line with 1 st premolar	7.14%	0%
In line with 2 nd premolar	64.2%	85.7%
In line with junction of 2 nd premolar & 1 st molar	14.2%	14.2%

Table 5. Showing the comparison of mean distance from the IOF-IOM in different studies reported. IOF: infraorbital foramen, IOM: infraorbital margin.

Study & Year	Distance from IOF-IOM (mm)
Hindy & Abdel-Raouf,1993	6.10
Chung et al.,1995	8.60
Silva et al.,1998	6.80
Canan et al.,1999	Females:8.30; Males:10.90
Aziz et al.,2000	Females:7.80; Males:8.50
Kazkayasi et al.,2001	7.19
Karakas et al.,2002	6.70
Elias et al.,2004	6.77
Agthong et al. ,2005	7.9
Apinhasmit et al. ,2006	Females:8.71; Males:9.53
Gupta et al. ,2008	7.00
Lopes et al. ,2009	6.66
Macedo et al. ,2009	6.37
Ilayperuma et al.,2010	Females:9.02; Males:10.56
Boopathi et al.,2010	6.57
Singh et al.,2011	6.16
Lokanayaki et al.,2013	6.32
Elsheikh et al. ,2013	6.53
Ukoha et al.,2014	7.38
Aggarwal et al.,2015	6.32
Veeramuthu et al.,2016	7.00
Nanayakkara et al. ,2016	6.91
Masabni & Ahmad ,2017	6.60
Our study*	5.67

Table 6. Showing the comparison of mean distance from the IOF to the ANS in different studies reported. IOF: infraorbital foramen, ANS: anterior nasal spine.

Study & Year	Distance from IOF to the ANS (mm)
Agthong et al. ,2005	Females:32.9; Males:34.9
Lopes et al.,2009	35.0
Singh et al.,2011	36.6
Gnanagurudasan <i>et al.</i> , 2014	Females: 33.6; Males:36.1
Ukoha et al.,2014	29.0
Singh et al.,2015	36.6
Nanayakkara et al.,2016	Females:32.8; Males:34.3
Veeramuthu et al.,2016	33.0
Cisneiros de Oliveira et al., 2016	Females: 34.0; Males:36.0
Our study*	33.3

Table 7. Showing the comparison of mean distance from the IOF to the NA in different studies reported. IOF: infraorbital foramen, NA: nasion.

Study & Year	Distance from IOF to the Na (mm)
Przygocka et al.,2012	44.76
Gnanagurudasan <i>et al.</i> ,2014	Females: 31.4; Males:38.2
Singh et al.,2015	44.95
Nanayakkara et al.,2016	42.44
Our study*	40.90

in the same plane as SOM was 21.4% on left side and 35.7% on right side. In relation to the sockets of the maxillary teeth, it was observed that most of the IOF's were in line with the 2nd premolar (85.7% on left side and 64.2% on right side) while few were in line with 1st premolar (0% on left side and 7.14% on right side).

Discussion

The infraorbital nerve and foramen are significant areas to discuss in dental surgeries due to the fact that the nerve is responsible for the sensory innervation of the maxillary region. Since it is supplying a large area, it is very important to know the exact location of IOF while inducing local anesthesia to block the nerve passing it. Due to its inconstant positions, a wide number of studies conducted in the past have documented the location of IOF in relation with surrounding bony landmarks. Although many studies appear in the literature from different populations, there is no detailed study on south Indian population so far. Hence, in this study, we determined the shape, diameters and location of the IOF in 28 sides of skulls obtained

from the region. Most common shape of IOF observed in our sample is oval shape (85.7% on right side and 71.4% on left side). Many other studies also found that the IOF was predominantly of oval shape followed by circular, semilunar and triangular shapes. In our study we didn't encounter any semilunar and triangular shapes. The frequency of multiple/accessory IOF has been widely reported. In the year 1875, Gruber reported that the number of accessory IOF may vary from 1 to 5 as reported by Leo et al. (Leo et al., 1995). A study by Cisneiros de Oliveira et al. (Cisneiros de Oliveira et al., 2016) reported that the multiplicity of IOF was found to be 10.7% in sample studied and most of the other studies also reported their frequency ranging from 4% to 11% (Gour et al., 2006; Singh, 2011; Gnanagurudasan *et al.*, 2014). Most of the studies also suggest that there is no significant difference in relation to the sex and sides. In our study, the frequency of multiple or accessory IOF was found to be 14.2%. However, higher incidences have been reported from a study on Indian population by Boopathi et al. (16.25%) (Boopathi et al., 2010) And in Mexican population by Berry (18.2%) (Berry, 1975).

In present study, the mean vertical and transverse diameters on the left and right sides were 3.82mm, 3.86mm and 3.95mm, 3.70mm respectively. These findings are compared with other studies conducted on different regions of Indian population and diameters are not exactly the same (Boopathi et al., 2010; Gour et al., 2006; Singh, 2011; Lokanayaki, 2013; Aggarwal et al., 2015; Veeramuthu et al., 2016). Previously published literature mentioning the distance between IOF and IOM are compared with results of our study in (Table 5). The minimum –maximum distance between IOM-IOF has been in a range from 5.7 mm to 10.9 mm respectively. Gnanagurudasan *et al.*, 2015, reported that this distance was significantly greater on the right side, which is in contrast to the report of Macedo et al. (Macedo et al., 2009) wherein the distance was greater on the left side. In our study, the distance was found to be 5.85mm on left side and 5.49mm on right side with no significant difference between the sides. This is similar to a study reported by Singh et al. (Singh, 2011) but greatly varies from other studies of the Indian population (Boopathi et al., 2010; Gour et al., 2006; Lokanayaki, 2013; Aggarwal et al., 2015; Veeramuthu et al., 2016; Singh et al., 2015). This could be due to geographical and genetic/ ethnic differences.

With regards to the distance from IOF to ANS and NA, we did not find any difference between sides. These findings are in agreement with the studies originated from Nigeria (Ukoha et al., 2014), Brazil (Cisneiros de Oliveira et al., 2016) and India (Singh, 2011; Veeramuthu et al., 2016) (Table 6, 7). However, contrary to these observations, Agthong et al.; Cisneiros de Oliveira et al. reported that the distance between IOF and ANS varied significantly between the sexes and sides of the crania. The distance between IOF and NA in our study found to be 40.39mm on the left side and 41.45mm on the right side. These values are found to be lower when compared to those of other studies (Table 7). It is quite obvious that the distances from IOF-IOM, IOF-ANS, and IOF-NA are variable among different population studies, a point which emphasizes the significance of meticulous preoperative evaluation of the IOF in facial/dental surgeries.

Our study showed that the majority of the IOF were located lateral to the vertical plane passing through the SOF. The prevalence was 57% on the left side and 50% on the right side. These results agree with the findings of Thai and Korean populations. The occurrence of IOF in the same vertical plane of SOF was recorded to be

21.4% on the left side and 35.7% on the right side which goes along with the observations found in the Thai (23.4%) (Agthong et al., 2005) and Korean (38.1%) (Chung et al., 1995) populations, respectively.

With regards to the maxillary teeth, our study found that the IOF was frequently located in a vertical plane passing through the 2nd premolar teeth (85.7% on the left side and 64.2% on the right side). Our results support the findings of Thai (Agthong et al., 2005) and Egyptian (Elsheikh et al., 2013) populations. However, according to Aziz et al. the IOF was located in a vertical plane through the 1st premolar. In our study the incidence of this was found to be 0% on the left side and 7.14% on the right side.

The infraorbital nerve is the nerve of choice for regional anesthesia while performing surgeries in mid-face areas. The results of this and previous studies indicate that the IOF's location, size, shape and its distance from important landmark differs in different populations. These findings are valuable not only in orbital surgeries and Caldwell-Luc operation but also while inducing local anesthesia (Masabni & Ahmad, 2017).

Conclusion

The risk associated with surgeries in the maxillofacial area could be reduced if the surgeons are aware of these studies and this will help the surgeon to avoid injures to the neurovascular bundle of IOF. Various studies conducted on the skulls of Indian population show minor to major differences in the measurements suggesting that many more studies are to be conducted to see whether the people of India are a pool of dissimilar genes? And also it is important to mention that the sample of our study was limited, hence future studies with larger sample are needed.

Author's contributions

Dr. Bhagath Kumar Potu, Dr. Gowtham Chandra Srungavarapu - contributed to the study design, standardizing the methodology, data collection and statistical analysis. Dr. Thejodhar Pulakunta – contributed to literature review and in setting up the research objectives.

Disclosure of interest

Authors have “no conflict of interests” related to the study and manuscript.

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