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CLINICAL RESEARCH:

Morphometric analysis of the infraorbital groove, canal, and foramen on computed tomography scans of an Iranian population

Análisis morfométrico del surco, canal y foramen infraorbitario en tomografías computarizadas de una población iraní

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ABSTRACT: This study morphometrically assessed the infraorbital groove (IOG), canal (IOC) and foramen (IOF) on computed tomography (CT) scans of an Iranian population. This cross-sectional study evaluated the CT scans of 126 patients presenting to a hospital in Qazvin city, Iran during 2020-2022, who were selected by convenience sampling. An oral and maxillofacial surgeon and an oral and maxillofacial radiologist identified the relevant anatomical landmarks and the measurements were made by a trained senior dental student. Data were analyzed by independent t-test, and Pearson's correlation test (alpha=0.05). The mean IOC length was 9.86±1.34 mm, the mean IOG length was 12.78±1.57 mm, the mean IOC-IOG angle was 136.78±6.90 degrees, the mean IOC-vertical plane angle was 26.92±5.74 degrees, the mean IOC-horizontal plane angle was 58.54±6.18 degrees, the mean horizontal distance between the IOF and the sagittal plane passing through the supraorbital notch (SON) was 4.85±0.98 mm, the mean horizontal distance between the IOF and the sagittal plane passing through the midline was 23.04±2.90 mm, the mean vertical distance between the IOF and infraorbital rim (IOR) was 9.22±1.45 mm, the mean distance between the IOF and anterior nasal spine (ANS) was 27.63±10.99 mm, the mean angle between the IOF and ANS was 33.52±5.46 degrees, and the mean soft tissue thickness over the IOF was 10.60±2.04 mm. No significant difference was found in the parameters based on age (P>0.05). IOF-midline and IOF-IOR distances were significantly greater in males than females (P<0.05).

No other significant differences were found based on gender (P>0.05). According to the results, the IOF-midline and IOF-IOR distances were significantly greater in Iranian males than females. The obtained results regarding the position of IOC, IOF, and IOG on CT scans of the Iranian study population can help maximize the success of related clinical procedures.

KEYWORDS: Computed tomography; Infraorbital groove; Infraorbital canal; Infraorbital foramen.

RESUMEN: Este estudio evaluó morfométricamente el surco infraorbitario (IOG), el canal (IOC) y el foramen (IOF) en tomografías computarizadas (TC) de una población iraní. Este estudio transversal evaluó las tomografías computarizadas de 126 pacientes que se presentaron en un hospital en la ciudad de Qazvin, Irán, durante 2020-2022, que fueron seleccionados por muestreo de conveniencia. Un cirujano oral y maxilofacial y un radiólogo oral y maxilofacial identificaron los puntos de referencia anatómicos relevantes y las mediciones fueron realizadas por un estudiante de odontología capacitado. Los datos se analizaron mediante una prueba t independiente y una prueba de correlación de Pearson (alfa=0,05). La longitud media del IOF fue de 9,86±1,34 mm, la longitud media del IOG fue de 12,78±1,57 mm, el ángulo medio del IOF-IOG fue de 136,78±6,90 grados, el ángulo medio del plano vertical del IOF fue de 26,92±5,74 grados, el ángulo medio del plano horizontal del IOF fue de 58,54±6,18 grados, la distancia horizontal media entre el IOF y el plano sagital que pasa por la escotadura supraorbitaria (SON) fue de 4,85±0,98 mm, la distancia horizontal media entre el IOF y el plano sagital que pasa por la línea media fue de 23,04±2,90 mm, la distancia vertical media entre el IOF y el reborde infraorbitario (IOR) fue de 9,22±1,45 mm, la distancia media entre el IOF y la espina nasal anterior (ANS) fue de 27,63±10,99 mm, el ángulo medio entre el IOF y el ANS fue de 33,52±5,46 grados y el grosor medio del tejido blando sobre el IOF fue de 10,60±2,04 mm. No se encontraron diferencias significativas en los parámetros en función de la edad (P>0,05). Las distancias IOF-línea media y IOF-IOR fueron significativamente mayores en hombres que en mujeres (P<0,05). No se encontraron otras diferencias significativas en función del género (P>0,05). Según los resultados, las distancias IOF-línea media y IOF-IOR fueron significativamente mayores en hombres iraníes que en mujeres. Los resultados obtenidos con respecto a la posición de IOC, IOF e IOG en las tomografías computarizadas de la población de estudio iraní pueden ayudar a maximizar el éxito de los procedimientos clínicos relacionados.

PALABRAS CLAVE: Tomografía computarizada; Surco infraorbitario; Canal infraorbitario; Foramen infraorbitario.

INTRODUCTION

The infraorbital foramen (IOF) is among the most important facial foramina (1). The infraorbital canal (IOC) is located in the maxillary bone in the anterior aspect of the orbital floor and has a superior-lateral path. The IOC opens right beneath the orbital margin through the IOF. The infraorbital groove (IOG) is located in the maxillary bone in the posterior aspect of the orbital floor and originates from the infraorbital fissure (2). The infraorbital nerves and the vasculature path through these structures. The infraorbital nerve is the continuation of the maxillary nerve that enters the orbit through the inferior orbital fissure, continues in the IOG, and finally enters the face through the IOC, innervating the lower eyelid, upper lip, nasal alae, maxillary sinus mucosa, and premolar teeth (2-4).

Surgeons should have sufficient knowledge about the location of IOF for procedures such as the infraorbital nerve block for anesthesia induction for procedures such as cyst drainage, cleft lip and palate surgery, endoscopic sinus surgery, and also when facial periosteal dissection is required as in maxillary osteotomy or mid-face lift surgery (1, 5, 6). Also, knowledge about the precise position of the IOF, IOC, and IOG is imperative for oral and maxillofacial surgeons, plastic surgeons, and ENT specialists for induction of local nerve blocks to minimize complications in placement of malar, submalar, or paranasal implants (2, 4). General anesthesia in combination with a nerve block has been reported to decrease the required depth of inhalation anesthesia and postoperative pain. Moreover, neurotomy of the inferior alveolar nerve by radiofrequency ablation is beneficial and less invasive than other procedures for patients with trigeminal neuralgia.

The infraorbital anesthesia techniques include the intraoral and extraoral techniques. In the intraoral technique, the canine tooth and canine fossa are used as anatomical landmarks to identify the needle insertion site, and the needle should be inserted more deeply into the tissue. In the extraoral technique, a shorter length of needle should be inserted through the skin to directly access the area. Thus, knowledge about the position of IOF, IOC, and IOG, and identifying the IOF under the soft tissue by the tactile sense are important for a safe anesthesia and to prevent injury to the adjacent structures.

Although the anatomy of these structures has been well studied on dry skulls and cadavers, such studies have limitations and do not allow precise measurement of the soft tissue thickness and intra-bony length of the IOC and IOG, or assessing the the changes of these structures over time. Moreover, assessment of their angulation relative to the hypothetical lines is difficult on dry skulls. However, recent technological advancements such as the use of computed tomography (CT)-based models enhance the understanding of the precise anatomy and pathologies of the hard tissues in living individuals. This novel technology minimizes errors and aids in detection of new imaging landmarks (1, 2, 4).

Considering the gap of information regarding the position of IOF, IOC, and IOG in the Iranian population using CT, this study aimed to morphometrically assess the position of IOF, IOC, and IOG in an Iranian population using CT.

MATERIALS AND METHODS

This cross-sectional study was conducted on CT scans of 126 patients presenting to Shahid Rajaie Hospital in Qazvin city, Iran during 2020-2022, who were selected by convenience sampling. The CT scans had been taken for purposes not related to this study such as preoperative assessment of cases with maxillofacial trauma, or patients undergoing cosmetic or other types of surgical procedures. The study protocol was approved by the ethics committee of Qazvin University of Medical Sciences (IR.QUMS.REC.1402.023).

SAMPLE SIZE

The sample size was calculated to be 126 patients (252 sides) according to the mean and standard deviation values reported by Hwang *et al.,* (2) statistical significance of 5%, and study power of 20% (2).

ELIGIBILITY CRITERIA

The inclusion criteria were available CT scans of patients presenting to Shahid Rajaie Hospital in Qazvin city, Iran during 2020-2022 who had no evidence of traumatic injuries, neoplastic lesions, syndromes, congenital anomalies, or inflammatory conditions affecting the anatomy of the maxillary bone.

The exclusion criteria were CT scans of patients with facial fractures or asymmetries, or presence of artifacts preventing accurate measurements.

RADIOGRAPHIC ASSESSMENTS

Initially, the anatomical landmarks related to the variables were identified by an oral and maxillofacial surgeon and an oral and maxillofacial radiologist If the two observers did not agree on the location of the anatomical landmarks, an experienced oral and maxillofacial radiologist would guide them to reach a single decision. Next, the following parameters were measured by a trained senior dental student (Figure 1):

IOG length: The sum of IOG length not covered by bone, the part parallel to the orbital floor, and the part covered with bone.

IOC length: The distance between the center of IOF and the point where the IOC axis changes its direction.

IOC-IOG angle: The angulation of IOC axis relative to the IOG axis was measured to determine the anatomical relationship of IOC and IOG.

Angle between IOC and vertical/horizontal plane: The angle formed between the IOC and the vertical and horizontal planes was also measured (this angle would help determine the correct direction of needle entry relative to the IOC angulation). The horizontal line was considered as the horizontal plane in this study, which passed through the center of IOF. The vertical line passing through the center of IOF was considered as the vertical plane.

Distance between IOF and supraorbital notch (SON): The horizontal distance between the IOF and the sagittal plane passing through the SON in the same vertical plane.

IOF-midline distance: The horizontal distance between the IOF and the sagittal plane passing through the midline in the same vertical plane.

Distance between IOF and infraorbital rim (IOR): Vertical distance between the IOF and IOR

Distance and angle between IOF and anterior nasal spine (ANS): The angle formed between the IOF and ANS axes and the distance between the

IOF and ANS were also measured to determine the position of IOF relative to the ANS.

Soft tissue thickness: The thickness of soft tissue over the IOF in parasagittal planes.

IMAGE RECONSTRUCTION

All measurements were made on the CT scans of patients. The CT scans had been taken by the same CBCT scanner (Somatom Emotion 16-slice; Netherlanda) with 110 kV tube potential, 35 mAs effective tube current, 8.18 s scanning time, and 16x0.6 mm field of view, and had been saved in DICOM format. Marco Pacs division–medical application (Novn Yadman, Iran) was used for image reconstruction and observation on a 19-inch monitor (Samsung; Seoul, South Korea). The reliability of all measurements was ensured by a postgraduate student of oral radiology. To ensure optimal reliability of the measurements, 10% of the images were randomly selected and remeasured by the same examiner after a 6-week period. The intra-examiner reliability was found to be 100%. Also, the examiner discussed the suspected cases with a second examiner, and the respective case was entered the study only if a consensus was reached. Otherwise, the respective case would be excluded (n=1).

STATISTICAL ANALYSIS

Data were analyzed by SPSS version 24 (SPSS Inc., IL, USA) at 0.05 level of significance. Comparisons between males and females and right and left sides were performed by independent t-test and the categories of age were evaluated using analysis of variance (ANOVA).

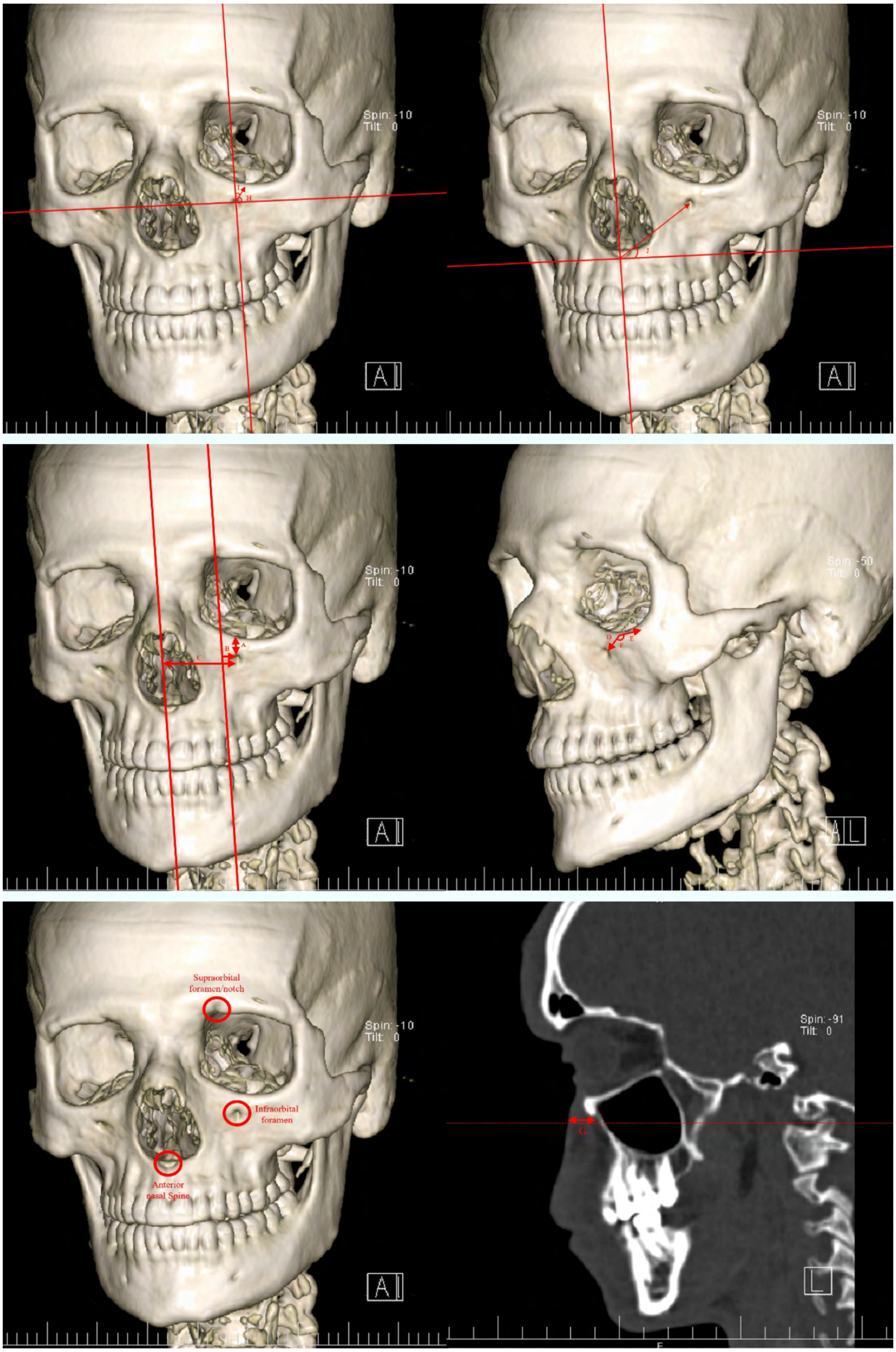

Figure 1. Radiographic identification of landmarks; (A) IOF-IOR distance; (B) IOF-SON distance; (C) IOF-midline distance; (D) IOC length; (E) IOG length; (F) IOC-IOG angle; (G) soft tissue thickness; (H) IOC-horizontal plane angle; (I) IOC-vertical plane angle; (J) IOF-ANS angle.

RESULTS

The CT scans of 126 patients including 87 males and 39 females between 18 to 65 years were evaluated. Table 1 and Table 2 present the measured variables in males and females and also in different age groups.

IOC LENGTH

The mean IOC length was 9.89±1.34 mm; this value was 9.96±1.46 mm in the right side and 9.77±1.42 mm in the left side. The mean IOC length was not significantly different in males and females (P=0.239). The mean right (P=0.242) and left (P=0.275) IOC lengths were not significantly different between males and females either. Different age groups had no significant difference in total IOC length (P=0.229), right side IOC length (P=0.225) or left side IOC length (P=0.359).

IOG LENGTH

The mean IOG length was 12.78±1.57 mm; this value was 12.94±1.69 mm in the right side and 12.63±1.78 mm in the left side. The mean IOG length was not significantly different in males and females (P=0.950). The mean right (P=0.948) and left (P=0.833) IOG lengths were not significantly different between males and females either. Different age groups had no significant difference in total IOG length (P=0.832), right side IOC length (P=0.573) or left side IOC length (P=0.953).

IOC-IOG ANGLE

The mean IOC-IOG angle was 136.78±6.90 degrees; this value was 137.20±7.91 degrees in the right side and 136.36±8.97 degrees in the left side. The mean IOC-IOG angle was not significantly different in males and females (P=0.843). The mean right (P=0.517) and left (P=0.685) IOC-IOG angles were not significantly different between males and females either. Different age groups had no significant difference in total IOC-IOG angle (P=0.445), right side IOC-IOG angle (P=0.547) or left side IOC-IOG angle (P=0.348).

IOC-VERTICAL PLANE ANGLE

The mean IOC-vertical plane angle was 26.92±5.74 degrees; this value was 27.75±6.89 degrees in the right side and 26.09±6.17 degrees in the left side. The mean IOC-vertical plane angle as not significantly different in males and females (P=0.789). The mean right (P=0.660) and left (P=0.955) IOC-vertical plane angles were not significantly different between males and females either. Different age groups had no significant difference in total IOC-vertical plane angle (P=0.174), right side IOC-vertical plane angle (P=0.097) or left side IOC-vertical plane angle (P=0.252).

IOC-HORIZONTAL PLANE ANGLE

The mean IOC-horizontal plane angle was 58.54±6.18 degrees; this value was 57.63±7.72 degrees in the right side and 59.45±6.40 degrees in the left side. The mean IOC-horizontal plane angle was not significantly different in males and females (P=0.268). The mean right (P=0.245) and left (P=0.406) IOC-horizontal plane angles were not significantly different between males and females either. Different age groups had no significant difference in total IOC-horizontal plane angle (P=0.174), or right-side IOC-horizontal plane angle (P=0.443). However, this difference was significant in the left side IOC-horizontal plane angle (P=0.038), such that a significant difference was found in this regard only between 24-31 and 41–66-year-old age groups, and by an increase in age, the IOC angulation approximated the horizontal plane.

DISTANCE BETWEEN IOF AND THE SAGITTAL PLANE PASSING THROUGH THE SON

The mean horizontal distance between the IOF and the sagittal plane passing through the SON was 4.85±0.98 mm. This value was 5.06±1.17 mm in the right side and 4.64±1.20 mm in the left side. This distance was not significantly different in males and females (P=0.085). The mean distance in the right (P=0.138) and left (P=0.166) sides was not significantly different between males and females either. Different age groups had a significant difference in the mean horizontal distance between the IOF and sagittal plane in total (P=0.039), but not in the right (P=0.143) or left side (P=0.502).

IOF-MIDLINE HORIZONTAL DISTANCE

The mean IOF-midline horizontal distance was 23.04±2.90 mm. This value was 23.16±3.08 mm in the right side and 22.92±3.04 mm in the left side. The mean IOF-midline horizontal distance in males was significantly greater than that in females (P=0.041). The difference between males and females was also significant in the right-side (P=0.036) but not in the left side (P=0.074). Different age groups had no significant difference in the mean IOF-midline distance in total (P=0.520), right side (P=0.223) or left side (P=0.898).

IOF-IOR VERTICAL DISTANCE

The mean IOF-IOR vertical distance was 9.22±1.45 mm. This value was 9.14±1.50 mm in the right side and 9.30±1.76 mm in the left side. This distance was also significantly greater in males than females in total (P=0.012) and in the right side (P=0.002) but not in the left side (P=0.085). Different age groups had no significant difference in the mean IOF-IOR distance in total (P=0.974), right side (P=0.814) or left side (P=0.963).

IOF-ANS DISTANCE

The mean IOF-ANS distance was 27.63±10.99 mm. This value was 26.92±4.51 mm in the right side and 28.33±20.80 mm in the left side. This distance was not significantly different in males and females (P=0.625). The mean distance in the right (P=0.490) and left (P=0.239) sides was not significantly different between males and females either. Different age groups had no significant difference in the mean IOF-ANS distance in total (P=0.754), right side (P=0.839) or left side (P=0.275).

IOF-ANS ANGLE

The mean IOF-ANS angle was 33.52±5.46 degrees. This value was 33.71±6.83 degrees in the right side and 33.33±6.70 degrees in the left side. This angle was not significantly different in males and females (P=0.105). The mean distance in the right (P=0.223) and left (P=0.192) sides was not significantly different between males and females either. Different age groups had no significant difference in this angle in total (P=0.080), right side (P=0.373) or left side (P=0.095).

SOFT TISSUE THICKNESS

The mean soft tissue thickness was 10.60±2.04 mm. The difference in this parameter was not significant between males and females (P=0.775) or different age groups (P=0.558).

Table 1. Study variables in males and females.

Variable	Total	Females	Males	P-value
IOC	9.86 ± 1.34	9.62 ± 1.65	9.96 ± 1.16	0.239
RIOC	9.96 ± 1.46	9.50 (8.25, 11.05)	10.00 (9.00, 11.00)	0.275
LIOC	9.77 ± 1.42	9.50 (8.50, 10.75)	9.75 (9.00, 10.75)	0.242
IOG	12.78 ± 1.57	12.77 ± 1.62	12.79 ± 1.57	0.950
RIOG	12.94 ± 1.69	12.90 ± 1.45	12.96 ± 1.80	0.833
LIOG	12.63 ± 1.78	12.64 ± 2.10	12.62 ± 1.65	0.948
A(IOC_IOG)	136.78 ± 6.90	136.99 ± 8.61	136.69 ± 6.08	0.843
RA(IOC_IOG)	137.20 ± 7.91	136.72 ± 9.28	137.41 ± 7.31	0.685
LA(IOC_IOG)	136.36 ± 8.97	137.26 ± 11.18	135.96 ± 7.86	0.517
A(IOC_VP)	26.92 ± 5.74	26.85 ± 4.83	27.12 ± 5.95	0.789
RA(IOC_VP)	27.75 ± 6.89	27.81 ± 6.17	27.88 ± 7.10	0.955
LA(IOC_VP)	26.09 ± 6.17	25.89 ± 5.01	26.36 ± 6.48	0.660
A(IOC_HP)	58.54 ± 6.18	57.53 ± 6.66	58.92 ± 5.94	0.268
RA(IOC_HP)	57.63 ± 7.72	56.68 ± 8.80	58.03 ± 7.23	0.406
LA(IOC_HP)	59.45 ± 6.40	58.38 ± 6.29	59.81 ± 6.36	0.245
IOF_SON	4.85 ± 0.98	4.62 ± 0.94	4.95 ± 1.00	0.085
RIOF_SON	5.06 ± 1.17	4.83 ± 1.20	5.17 ± 1.16	0.138
LIOF_SON	4.64 ± 1.20	4.42 ± 1.06	4.73 ± 1.25	0.166
IOF_ML	23.04 ± 2.90	22.21 ± 2.98	23.39 ± 2.80	0.041
RIOF_ML	23.16 ± 3.08	22.28 ± 2.99	23.52 ± 3.06	0.036
LIOF_ML	22.92 ± 3.04	22.14 ± 3.29	23.25 ± 2.89	0.074
IOF_IOR	9.22 ± 1.45	8.70 ± 1.52	9.43 ± 1.36	0.012
RIOF_IOR	9.14 ± 1.50	8.53 ± 1.38	9.41 ± 1.48	0.002
LIOF_IOR	9.30 ± 1.76	8.86 ± 1.78	9.46 ± 1.70	0.085
IOF_ANS	27.63 ± 10.99	28.66 ± 19.07	27.14 ± 3.80	0.625
RIOF_ANS	26.92 ± 4.51	26.13 ± 5.13	27.24 ± 4.20	0.239
LIOF_ANS	28.33 ± 20.80	31.19 ± 37.08	27.03 ± 3.97	0.490
A(IOF_ANS)	33.52 ± 5.46	34.63 ± 4.97	32.99 ± 5.64	0.105
RA(IOF_ANS)	33.71 ± 6.83	34.81 ± 6.99	33.17 ± 6.77	0.223
LA(IOF_ANS)	33.33 ± 6.70	34.45 ± 6.28	32.81 ± 6.89	0.192
Skin Thickness	10.60 ± 2.04	10.69 ± 1.58	10.59 ± 2.23	0.775

R: Right side; L: Left side.
The results has been shown by Mean ± std. deviation.

Table 2. Study variables in different age groups.

Variable	15-23 years	24-31 years	32-40 years	41-66 years	P value
IOC	10.20 ± 1.18a	9.95 ± 1.27	9.53 ± 1.36a	9.70 ± 1.54a	0.229
RIOC	10.24 ± 1.32a	10.08 ± 1.46a	9.65 ± 1.43a	9.76 ± 1.65a	0.359
LIOC	10.15 ± 1.40a	9.82 ± 1.29a	9.42 ± 1.45a	9.64 ± 1.57a	0.225
IOG	12.75 (11.75, 14.00)a	12.75 (12.16, 13.50)a	12.62 (12.25, 13.25)a	12.50 (11.75, 13.46)a	0.832
RIOG	13.00 (12.00, 14.12)a	12.80 (12.00, 13.50)a	13.00 (12.00, 13.50)a	13.00 (11.80, 14.35)a	0.953
LIOG	12.50 (11.88, 13.70)a	13.00 (12.05, 13.47)a	12.50 (11.62, 13.38)a	12.15 (11.00, 13.50)a	0.573
A(IOC_IOG)	135.38 ± 6.91a	138.18 ± 7.16a	136.95 ± 6.55a	136.71 ± 7.15a	0.445
RA(IOC_IOG)	136.40 ± 8.45a	139.34 ± 7.14a	136.93 ± 7.03a	136.15 ± 8.99a	0.348
LA(IOC_IOG)	134.37 ± 7.49a	137.03 ± 9.86a	136.97 ± 9.81a	137.26 ± 8.89a	0.547
A(IOC_VP)	23.54 (21.31, 30.59)a	26.57 (22.69, 31.47)a	28.44 (25.93, 31.17)a	29.36 (25.45, 31.03)a	0.174
RA(IOC_VP)	24.62 (21.35, 30.94)a	28.94 (22.78, 32.90)a	29.12 (25.39, 32.57)a	29.88 (24.36, 32.30)a	0.252
LA(IOC_VP)	22.61 (21.19, 28.91)a	23.48 (21.21, 28.58)a	27.28 (25.14, 31.71)a	27.19 (23.97, 31.25)a	0.097
A(IOC_HP)	59.86 ± 5.71a	58.70 ± 6.41a	58.51 ± 5.42a	56.36 ± 6.83a	0.174
RA(IOC_HP)	59.23 ± 7.01a	56.80 ± 8.30a	57.96 ± 7.31a	56.23 ± 8.41a	0.443
LA(IOC_HP)	60.49 ± 6.07ab	60.60 ± 5.84a	59.06 ± 5.22ab	56.48 ± 7.38b	0.038
IOF_SON	4.75 (4.11, 5.00)a	4.75 (4.00, 5.00)a	5.00 (4.56, 5.25)a	5.25 (4.36, 5.79)a	0.039
RIOF_SON	5.00 (4.15, 5.50)a	5.00 (4.50, 5.50)a	5.25 (4.50, 5.50)a	5.00 (4.50, 6.00)a	0.501
LIOF_SON	4.50 (3.50, 5.03)a	4.20 (3.62, 4.90)a	5.00 (4.00, 5.50)a	5.00 (3.88, 5.50)a	0.143
IOF_ML	22.50 (21.00, 24.04)a	23.25 (21.85, 23.99)a	22.62 (21.56, 23.54)a	21.75 (21.12, 23.69)a	0.520
RIOF_ML	23.00 (21.00, 24.62)a	23.50 (21.50, 24.75)a	23.00 (21.77, 24.10)a	22.25 (21.00, 24.25)a	0.898
LIOF_ML	23.00 (21.00, 25.00)a	22.80 (22.00, 24.88)a	22.25 (21.00, 23.38)a	21.75 (21.00, 23.50)a	0.223
IOF_IOR	8.90 (8.75, 9.60)a	9.00 (8.75, 9.44)a	9.00 (8.75, 9.49)a	9.00 (8.25, 9.81)a	0.974
RIOF_IOR	8.80 (8.50, 10.07)a	9.00 (8.50, 10.00)a	9.00 (8.62, 9.50)a	8.75 (8.00, 9.85)a	0.814
LIOF_IOR	9.00 (8.50, 10.50)a	9.00 (8.50, 9.50)a	9.00 (8.62, 9.45)a	9.00 (8.43, 10.12)a	0.963
IOF_ANS	25.75 (23.62, 30.82)a	26.12 (24.12, 31.29)a	25.75 (24.17, 27.94)a	25.00 (23.25, 29.29)a	0.754
RIOF_ANS	25.35 (23.75, 31.62)a	26.00 (24.00, 31.38)a	25.50 (24.50, 29.00)a	25.00 (23.38, 29.52)a	0.839
LIOF_ANS	26.00 (23.50, 29.95)a	26.75 (24.00, 31.85)a	24.75 (23.50, 27.75)a	24.00 (22.50, 29.08)a	0.275
A(IOF_ANS)	31.36 ± 4.24a	34.20 ± 5.76a	34.59 ± 5.24a	33.89 ± 6.28a	0.080
RA(IOF_ANS)	30.55 (27.90, 35.72)a	34.53 (29.01, 39.67)a	34.17 (30.18, 39.52)a	34.20 (26.66, 40.14)a	0.373
LA(IOF_ANS)	30.80 ± 5.86a	33.73 ± 6.78a	34.68 ± 6.98a	34.24 ± 6.99a	0.095
Soft Tissue Thickness	10.15 (9.45, 11.07)a	10.25 (9.50, 11.00)a	10.50 (9.12, 11.00)a	10.75 (9.50, 11.68)a	0.558

R: Right side; L: Left side.
In each row, the different letters indicate a significant difference between the age categories (P-value<0.05).

DISCUSSION

This study morphometrically assessed the position of IOF, IOC, and IOG in an Iranian population using CT. According to the present results regarding the position of IOF, for local anesthesia administration, the surgeon should first identify the IOF, and then insert the needle superiorly and laterally. Since the IOC continues in the IOG in the orbital floor, it is important to insert the needle into the IOC, and not posteriorly into the IOG. If the needle is inserted too deep, it may accidentally enter the orbit. In the present study, the angulation of IOC relative to the IOG ranged from 130 to 143 degrees. It means that further penetration of the needle into the IOC posteriorly can traumatize the orbital or the pterygopalatine structures. Smaller angles close to 90 degrees can result in the insertion of needle into the orbit through its thin ssbone and IOG. Larger angles close to 180 degrees can result in needle entry into the ION, which is located at the proximal end of the IOG. Also, for more accurate identification of the position of IOC for needle insertion, the needle would better be inserted through the IOF in a direction parallel to the IOC axis. Thus, the IOC axis relative to the vertical and horizontal planes was also evaluated in the present study. The results revealed that the mean angle between the IOC and vertical plane was 26.92±5.74 degrees, and the mean angle between the IOC and horizontal plane was 58.54±6.18 degrees. However, in a study by Hwang *et al.*, (2) the mean IOC angle relative to the vertical and horizontal planes was 13.2±6.4 and 46.7±7.6 degrees, respectively. Difference between the reported values in their study and the present findings can be due to racial differences of the study populations, and differences in scanners, image processing algorithms, and the software programs used (2).

The mean IOC length was 9.86±1.34 mm in the present study while this value was 11.7 mm in the study by Hwang *et al.*, (2) 22.95 mm in a study by Kazkayasi *et al.*, (7) and 13 mm in a study by Rahman *et al.* (8).

The mean IOG length was 12.78±1.57 mm in the present study, which was higher than the value reported by Kazkayasi *et al.*, (7) (5.95 mm) and smaller than the value reported by Hwang et al., (2) (16.7 mm) and Rahman *et al.* (8) (14 mm). It should be noted that variations in the reported IOG lengths can be due to differences in study populations and definitions of IOC and IOG. In the present study, similar to that of Hwang *et al.*, (2) IOC and IOG were assessed and defined radiographically based on their clinical implications, and not visually (assessment on cadaver) or merely based on their anatomical position. In case of having sufficient knowledge about the direction of IOC, the surgeon can select the proper angulation of needle for insertion into the IOC. To acquire precise information regarding the angulation of IOC, the position of this canal should be evaluated on both vertical and horizontal planes. In the present study, the mean IOC-horizontal plane angle was 58.54±6.18 degrees and the mean IOC-vertical plane angle was 26.92±5.74 degrees. These angles were 44 and 12 degrees, respectively in a study by Hwang *et al.* (2). Also, the IOC-horizontal plane angle in the left side was significantly different between 24-31 and 41-66-year-old age groups. However, similar previous studies did not make any comparison in this regard among different age groups.

In the present study, the mean horizontal distance between the IOF and sagittal plane passing through the SON was 4.85±0.98, and the mean horizontal distance between the IOF and sagittal plane passing through the midline was 23.04±2.90 mm. Similarly, Hwang *et al.* (2) reported these values to be 5.6 and 26.5 mm, respectively. Also, Chung *et al.* (9) showed the distance between IOF and facial midline to be 27.2 mm. Variations in the reported values can be due to anatomical differences among different study populations and the effect of growth and development on the landmarks. The IOF-midline and IOF-IOR distances in the right side were significantly different between males and females in the present study. However, no such a comparison has been made in previous studies. The total mean IOF-midline distance was greater in males than females in the current study, which was in agreement with the results of Hwang *et al.*, (2). The mean IOF-IOR distance in males was also significantly greater than that in females in the current study. However, Hwang *et al.* (2) did not find any significant difference in this parameter between males and females. Such differences may be attributed to anatomical variations of different study populations and number of males and females evaluated in different studies. Previous studies considered SON, supraorbital foramen, facial midline, IOR, and ANS as the reference points for identification of IOF (1,2,7-9) and the distance between IOF and the abovementioned points was reported to be 4.85±0.98, 23.04±2.90, 9.22±1.45, and 27.63±10.99 mm, respectively. Chung *et al.* (9) indicated that IOF was located 27.2 mm far from the facial midline and had 34 mm distance from the ANS in a Korean population. Hwang *et al.* (2) reported that IOF had 26.5 mm distance from the midline while this distance was 25.7 mm in a study by Orhan *et al.* (1). Also, Chrcanovic *et al.* (10) reported that IOF was located averagely 6.5 mm below the IOR and had 32.38 mm distance from the ANS and 42.92 mm distance from the supraorbital foramen. However, the distance between the IOF and IOR was 9.6 mm in the study by Hwang *et al.*, (2) and 7.5 mm in the study by Orhan *et al.* (1). Variations in the reported values in the literature can be attributed to different definitions of the reference points (measurement from the superior border or center of foramen), measurement errors, and anatomical differences among different ethnic and racial groups.

Soft tissue thickness over the IOF was also evaluated in the present study, which has been less commonly evaluated in the literature. Estimation of soft tissue thickness over the IOF can help prevent over-insertion of needle and subsequent traumatization of orbit and the adjacent structures. The mean soft tissue thickness over the IOF was 10.60±2.04 mm in the present study. This value was 12 and 11.5 mm in studies by Hwang *et al.*, (2) and Dagistan *et al.*, (11) respectively. Also, Hwang *et al.* (2) indicated that soft tissue thickness over IOF increased with age in females while this increase was not statistically significant in the present study.

Some previous studies reported a change in the position of IOF with age (5,12). Facial bones experience a period of fast growth and development after 3-4 years of age. Also, it has been reported that the orbit matures at 16 years of age (1,13). However, the present study and that of Orhan *et al.* (1) found no significant difference in this regard among different age groups. It should be noted that the age range of the participants was 15-66 years in the present study and 18-70 years in the study by Organ *et al.*, (1) which means that growth had already been completed in the youngest age group in their study (18-25 years), and explains lack of a significant correlation with age.

In the present study and those of Chung *et al.*, (9) and Hwang *et al.*, (2) all landmarks were evaluated separately based on age and gender. Also, in the present study and that of Hwang *et al.*, (2) the right- and left-side landmarks were compared. However, Hwang *et al.* (2) did not separately report the results for each side. This study appears to be among the first to assess the correlation of IOF and anatomical landmarks in the right and left sides. Furthermore, CT was used in the present study to overcome the limitations of assessments on cadavers and dry skulls.

This study had some limitations as well. Variations in width and number of IOF can affect anesthetic injection into the IOC, because they can best be assessed directly on bones. Also, a wide range of variation in IOC-IOG angles existed in the present study, and the authors could not find any parameter to help predict this angle.

CONCLUSION

The present results helped in accurate identification of the position of IOF and its relationship with the adjacent anatomical structures. The obtained results regarding the position of IOC, IOF, and IOG on CT scans of the Iranian study population can help maximize the success of related clinical procedures.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization: M.V. and R.R.
Investigation: M.V. and F.T.D.
Review and editing: M.V.
Writing original draft: A.K. and A.A.
Data analysis: A.K. and M.T.
Visualization: F.T.D.
Writing final version: M.T. and L.T.
Resources: M.T. and A.A.
Results analysis: R.R.
Supervision: R.R. and L.T.

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