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Alignment of the Facial Foramina in Relation to Midline: 3D-Morphometric Study in a Brazilian Sample

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ABSTRACT
Introduction: the aim of this study was to evaluate the alignment of the supraorbital, infraorbital and mental foramina in relation to the midline according to the sex, the side and the dentition in a sample of CT skulls of a Brazilian sample by 3D morphometric analysis.
Methods: A total of 116 CT scans from adults dried human skulls and mandibles were selected at random ranging in age from 19 to 100 years (±57.31), both sexes. Measurements were performed in Rhinoceros 5 software from the median sagittal plane referenced. Continuous outcomes underwent the Shapiro-Wilk's normality test followed by Student's paired t test or Wilcoxon's test to check for differences. To correct the p-value for multiple comparisons, the Tukey's or Dunn's multiple comparisons post-hoc tests were also performed for One-Way ANOVA and Kruskal-Wallis test, respectively. The significance and confidence levels were set, respectively, at 5% and 95%.
Results: when the supraorbital, infraorbital, and mental foramina of the same side were compared, a statistically significant result occurred for all comparisons for both sides regarding male and female individuals ($p<0.0001$).
Conclusion: the present work showed in 3-D morphometric analysis that we did not find foramina alignment in any of those studied.
Keywords: Regional Anesthesia; Dental practice; Supraorbital foramen; Infraorbital foramen; Mental foramen.

Introduction

The study of facial anatomy is essential for the execution of clinical and surgical procedures in the extraoral regions, such as anesthetic block, corrective surgeries and aesthetic procedures[1,2] in order to prevent possible complications, such as hemorrhages, necrosis and paresthesia, caused by traumas in the vascular-nervous bundles.

The knowledge of the anatomical characteristics of craniofacial structures can be obtained by evaluating the incidence of anatomical variations, linear measurements on the surface of the structures, as well as the bi - or three - dimensional morphometric study in internal structures using medical images. The skull bones are widely studied due to the presence of anatomical variations. Among the different anatomical structures that are present in the skull, foramina and canals are the targets of research with clinical and surgical interest[3,4].

The use of medical images, such as computed tomography (CT) scans for craniofacial morphometric studies, is of great value since it consists of a diagnostic imaging method used as a complementary[5], noninvasive and high diagnostic accuracy test, in which generates a set of images from radiation, allowing the reproduction of a section of the body in any of the three planes of space.

Studies reporting the alignment and positioning of the supraorbital, infraorbital and mental foramina are scarce in the Brazilian literature, in the same way that existing data regarding the variations of positions related to sex and side are still scarce and controversial, as reported by Cutright *et al.*[6] and Agthong[7], that found a significant difference of measures between sexes, different from Aziz[8] and Saylam[9], who found no significant difference. The position of the facial foramina is important for regional block and for various maxillofacial surgical procedures.

The aim of this study was to evaluate the alignment of the supraorbital, infraorbital and mental foramina in relation to the midline according to the sex, the side and the dentition in a sample of CT scans of skulls of a Brazilian sample by 3D morphometric analysis.

Material and Methods:

The present study was approved by Ethics Committee from Piracicaba Dental School – University of Campinas (protocol number: 15045219.7.0000.5418).

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Sample

A total of 116 computed tomography (CT) scans from adults dried human skulls and mandibles were selected at random ranging in age from 19 to 100 years (±57.31) (Table 1), 45 female and 71 males, and acquired by the Aisteion Multislice 4 CT System (Toshiba Medical Systems Corporation - Japan), for the protocol of the skull: 100 MA, 120KV, with cuts of 1mm. The CT scans of skulls and mandibles belongs to a Bone Collection of the Forensic Dentistry Division from Piracicaba Dental School – University of Campinas.

In this study, were included CT scans that presented the data about sex and age, and the skull and mandible with preserved and intact anatomical structures, without macroscopic deformities. The condition about the dentition (complete dentate or edentulous) was considered.

CT scans with any anatomical abnormalities and/or bony fractures in the region of interest were excluded.

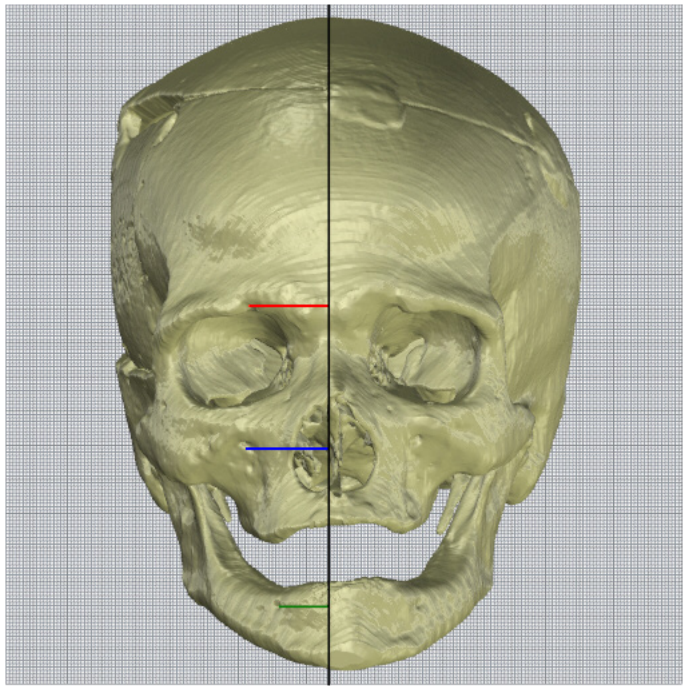

Figure 1. Measurements using 3D reconstruction of the skull (Rhinoceros 5 software-McNeel & Associates, Seattle, USA). The black line indicates the median sagittal plane reference. SOF-FML: red line; IOF-FML: blue line; MF-FML: green line.

Table 1. Means (years) of the sample used in the study.

	All	Males	Females	Males – edentulous	Males- dentulous	Females - edentulous	Females - dentulous
Mean (years)	57.31	54.00	59.58	54.00	53.54	64.42	63.56
Standard deviation	+/- 20.37	+/- 16.15	+/- 22.82	+/- 16.25	+/- 15.89	+/- 25.77	+/- 26.03

Protocol measurements on CT scans

The Mimics 18.0 software (Materialise, NV, Belgium) was used to produce the segmentation of the images on each CT scan. In segmentation, the region of interest (ROI) was selected. The segmentation was performed in both, right and left, sides of the facial bones in each skull. After the segmentation, the software procedure the three-dimensional (3D) reconstruction of each skull and mandible.

Measurements were performed according to the protocol proposed by Gupta[10] and adapted for CT by Lim *et al.*[11].

In 3D reconstruction, the measurements were performed in Rhinoceros 5 software (McNeel & Associates, Seattle, USA) from the median sagittal plane referenced by a line drawn on the bone surface, which reproduced the curvatures of the anatomical structures located on the midline. All measurements were done bilaterally. The following measures were considering (Figure 1):

1. SOF-FML = distance from the supraorbital foramen to the facial midline (mm);
2. IOF-FML = distance from the infraorbital foramen to the facial midline (mm);
3. MF-FML = distance from the mental foramen to the facial midline (mm).

Two investigators performed the measurements in separated periods to obtain the intra-class correlation coefficient.

Statistical analysis

Data were organized in Microsoft Excel (Microsoft Windows) sheets prior to statistical analysis, which was conducted on GraphPad Prism 6.01 (San Diego, CA, USA). Continuous outcomes underwent the Shapiro-Wilk's normality test followed by Student's paired t test or Wilcoxon's test to check for differences regarding the right and left sides; to check for differences between continuous outcomes at the same side (i.e. right versus right and left versus left sides), the Shapiro-Wilk's normality test was performed and followed by the One-Way ANOVA or the Kruskal-Wallis test. To correct the p-value for multiple comparisons, the Tukey's or Dunn's multiple comparisons post-hoc tests were also performed for One-Way ANOVA and Kruskal-Wallis test, respectively. Categorical outcomes were compared using the Fisher's exact test. The inter-rater agreement level was measured using the intra-class correlation coefficient. For all analysis, the significance and confidence levels were set, respectively, at 5% and 95%.

Results

The intra-class correlation coefficient showed an almost perfect agreement between assessors (ICC=0.994, 95% confidence interval: 0.988-0.996).

Except for measures involving SOF-FML, all continuous outcomes showed a statistically significant result for comparisons between right and left sides. Table 2 and Figure 2 summarize the results of continuous outcomes obtained in the present study.

When the supraorbital, infraorbital, and mental foramina of the same side were compared (i.e. right versus right or left versus left sides), a statistically significant result occurred for all comparisons for both sides regarding male and female individuals (right side, male = < 0.0001; right side, female = < 0.0001; right side, both = < 0.0001; left side, male = < 0.0001; left side, female = < 0.0001; left side, both = < 0.0001). Analysis regarding categorical outcomes showed no statistically significant differences (p>0.05).

Except for measures involving SOF-FML, all continuous outcomes showed a statistically significant result for comparisons between the right and left sides of dentulous and edentulous individuals. Table 3 and Figure 3 summarize these results.

Table 2. Means and standard deviations (SD +/-) obtained in each sex from measurements. SOF-FML = distance from the supraorbital foramen to the facial midline; IOF-FML = distance from the infraorbital foramen to the facial midline; MF-FML = distance from the mental foramen to the facial midline; SD = standard deviation. * = indicates a statistically significant result.

	SOF-FML					IOF-FML					MF-FML				
	Right side		Left side		p-value	Right side		Left side		p-value	Right side		Left side		p-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Male	24.80	+/- 4.079	24.68	+/- 4.207	0.8668	26.07	+/- 2.619	27.75	+/- 2.858	< 0.0001*	20.87	+/- 3.211	23.81	+/- 3.288	< 0.0001*
Female	22.70	+/- 4.787	22.05	+/- 4.947	0.5883	25.03	+/- 2.158	26.58	+/- 2.679	0.0004*	20.05	+/- 3.128	22.67	+/- 2.639	0.0013*
Both	23.98	+/- 4.460	23.62	+/- 4.678	0.9753	25.66	+/- 2.492	27.29	+/- 2.836	< 0.0001*	20.55	+/- 3.190	23.37	+/- 3.091	< 0.0001*

Table 3. Means and standard deviations (SD +/-). SOF-FML = distance from the supraorbital foramen to the facial midline; IOF-FML = distance from the infraorbital foramen to the facial midline; MF-FML = distance from the mental foramen to the facial midline; SD = standard deviation. * = indicates a statistically significant result.

	SOF-FML					IOF-FML					MF-FML				
	Right side		Left side		p-value	Right side		Left side		p-value	Right side		Left side		p-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Edentulous	24.01	+/- 4.221	23.32	+/- 4.441	0.3956	25.61	+/- 2.491	26.80	+/- 2.699	0.0058*	20.15	+/- 3.297	22.74	+/- 3.201	< 0.0001*
Dentulous	24.19	+/- 4.635	23.68	+/- 4.690	0.5424	25.82	+/- 2.531	27.31	+/- 2.780	0.0007*	20.99	+/- 3.014	23.40	+/- 3.133	< 0.0001*

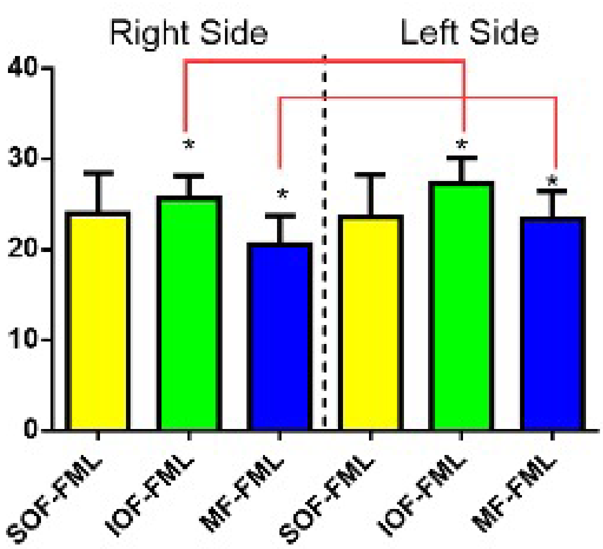

Figure 2. Means and standard deviation of continuous outcomes regarding right and left sides involving all individuals. SOF-FML = distance from the supraorbital foramen to the facial midline; IOF-FML = distance from the infraorbital foramen to the facial midline; MF-FML = distance from the mental foramen to the facial midline; * = indicates a statistically significant result for comparisons between right and left sides.

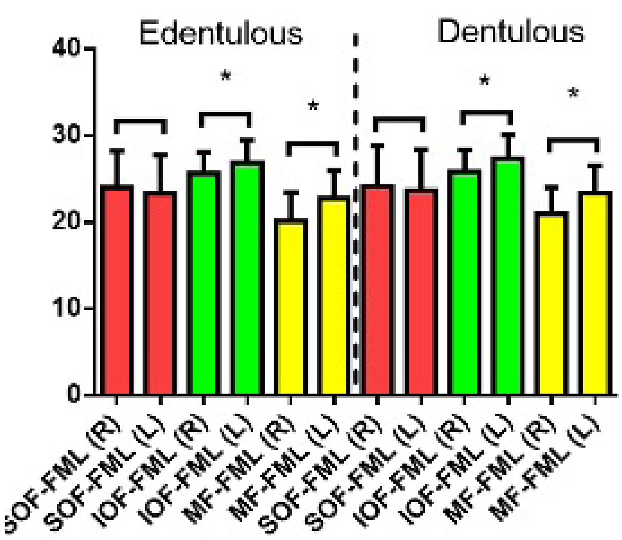

Figure 3. Means and standard deviations of continuous outcomes regarding right versus left sides involving dentulous and edentulous individuals. SOF-FML = distance from the supraorbital foramen to the facial midline; IOF-FML = distance from the infraorbital foramen to the facial midline; MF-FML = distance from the mental foramen to the facial midline. * = indicates a statistically significant result.

When the supraorbital, infraorbital, and mental foramina of the same side were compared in dentulous and edentulous individuals, a statistically significant result occurred for multiple comparisons in both sides (right side, edentulous = < 0.0001; right side, dentulous = < 0.0001; left side, edentulous = < 0.0001; left side, dentulous = < 0.0001). Table 4 and Figure 4 summarize these results.

Table 4. Means and standard deviations (SD +/-). SOF-FML = distance from the supraorbital foramen to the facial midline; IOF-FML = distance from the infraorbital foramen to the facial midline; MF-FML = distance from the mental foramen to the facial midline; SD = standard deviation. * = indicates a statistically significant result.

	SOF-FML		IOF-FML		MF-FML			SOF-FML		IOF-FML		MF-FML		
	Right side		Right side		Right side		p-value	Left side		Left side		Left side		p-value
	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD	
Edentulous	24.01	+/- 4.221	25.61	+/- 2.491	20.15	+/- 3.297	< 0,0001*	23.32	+/- 4.441	26.80	+/- 2.699	22.74	+/- 3.201	< 0,0001*
Dentulous	24.19	+/- 4.635	25.82	+/- 2.531	20.99	+/- 3.014	< 0,0001*	23.68	+/- 4.690	27.31	+/- 2.780	23.40	+/- 3.133	< 0,0001*

Discussion

The present work performed a descriptive observational study of the anatomical characteristics of facial foramina in three-dimensional models of dry skulls obtained from CT scans. This information will provide details of extreme value and importance for performing various procedures on the face and help surgeons to execute, more safely, nerve blocks and periosteal dissections around the facial foramina.

Facial foramina are noble structures which important nerves and vessels emerge[12]. From a surgical point of view, they are located near important regions, such as the oral, orbital and nasal regions. Therefore, it is relevant for dental and medical professionals to know its exact location[13], for better execution of maxillofacial, aesthetic, and anesthetic surgical procedures[14]. The SOF is an extremely important structure in maxillary facial surgeries, especially in plastic eye surgery, biopsies, blepharoplasty and even in hair transplants, besides the supra nerve block. orbital, it is usually made in the foramen region[15]. The IOF is the structure to be bathed by the anesthetic solution for the dental treatment of the maxillary incisors and canines, and it is also the structure that should be avoided having botulinum toxin in an eventual correction of gingival smile[16]. The importance of IOF, and its location, also extends to the area of maxillofacial surgery, orbital floor reconstructions, and Caldwell-Luc accessions[17, 18]. MF studies show that it may vary in height in relation to the mandibular base, position in relation to the lower teeth and its shape, oval or rounded[19]. In addition to these characteristics, MF can be variable among populations[20], justifying further studies.

In the present work, the sex of the skulls was considered, although the locations of the foramina are known, the study concluded here is in a mixed population and it is known that there may be anatomical variation due to differences in craniofacial biotype and morphology[21]. A concept that may also explain the differences between our results, which found that there is a significant difference in the position of the foramina for both sides between sexes according to table 1, unlike Aziz[8] and Saylam *et al.*[9], which found no significant difference.

The present results revealed statistical differences when comparing the right and left sides of all skulls, except for the SOF, partially expected data, because in a sample of skulls the side differences could be explained due to the increased function of a preferred chewing side, random asymmetry of the facial skeleton or, in edentate mandibles, the preferred chewing side became the hemiarch with longer duration of the dentate period[22].

About the dentition variable, was verified that the dental status significantly influenced foramina in maxilla and mandible. The results showed that the IOF was the furthest from the midline and the MF was the closest. This result was in contrasted with the Gupta *et al.* that in most cases (more than 80%), the SOF, the IOF and the MF were in same sagittal plane. Our results agree with Nanayakkara *et al.*[23] that most of the skulls, the IOF were located lateral to the vertical plane. These skulls, during aging, accompanied by total tooth loss, show severe changes in this region of the face, including depth and height[24], which may explain our results on the statistical difference for the teeth, the location of the IOF.

In case of SOF, the absence of results may be due to the region in which it is located, since the main structural changes due to aging occur in the middle third of the face, especially in the regions of the orbital margins and the piriform aperture of the maxilla, which reach the peak of projection in adulthood and progressively lose volume[24]. The SOF was not influenced because its location is in frontal bone, not affected by the structural changes caused by the dentition, especially the reduction of teeth, jaw height, resulting in decreased height of the lower and middle thirds of the face[25].

Conclusion

In conclusion, the present work showed in 3-D morphometric analysis the non-presence of the foramina alignment, that should be taken into consideration with special attention to the Brazilian population mainly during surgical manipulation and administering regional nerve block.

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