Morphometric study of the key foramina for maxillofacial practice in dry adult skulls and mandibles of Egyptian population

Samah M. M. Abozaid and Medhat A. Salah
Anatomy Department, Faculty of Medicine, Minia University

Abstract
Inferior orbital foramen (IOF), greater palatine foramen (GPF) and mandibular foramen (MF) are important foramina for various surgical procedures. The aim of the present study is to locate the proper anatomical site of these foramina in relation to nearby anatomical landmarks and the proper length of needle penetration into pterygopalatine fossa. A total of 50 adult dry skulls and mandibles of Egyptian population were collected and examined. Sex was determined using gross anatomical features. All foramina were morphometrically examined. All measurements were taken on both sides with Vernier caliper and flexible inelastic tape. For the IOF the dimensions of the foramen, the distance between foramen and inferior orbital margin (IOF-IOM), maxilla (IOF- MAXILLA), anterior nasal spine(IOF-ANS), nasion (IOF-NASION) and to external acoustic meatus (IOF-EAM). For the GPF the distance between center of GPF and intermaxillary suture (GPF-Medline), to 3rd maxillary molar teeth (GPF-3rd molar) and the length of the needle penetration into pterygopalatine fossa GPF (DEPTH). For the MF the distance between mandibular foramen to the anterior border of the ramus (AB-MF), posterior border of the ramus (PB-MF), mandibular notch (MF-MN), base of the mandible and third molar (MF-MB) were measured. Sex and side difference was tested statistically. For side difference the mean (IOF-IOM) was 7±1.16mm on the right side and 7±0.899 mm on the left. The mean (IOF- MAXILLA) was 28.14±4.49mm on the right side and 29.71±3.199 mm on the left. The GPF (DEPTH) was 18.57±2.15mm and 18.43±1.99mm on right and left side respectively. The AB-MF was 17.8±3.4mm and 18.8±2.05mm on right side and left side respectively, PB-MF was 11.2±1.79mm and 11±1.4mm on right side and left side respectively, MF-MN was 22.4±2.3mm and 20.4±3.36mm on right side and left side respectively and MF-MB was 28.4±3.78mm 28.2±2.95mm on right side and left side respectively. No significant sex difference reported in all studied variables.
Conclusion: Accurate localization of these key foramina is possible and important in maxillofacial practice and local anesthesia to decrease failure rate and prevent subsequent complications
Keywords: inferior orbital foramen, greater palatine foramen, mandibular foramen, Egyptian population, dry skulls, morphometric
Corresponding author: Samah Mohammed Mahmoud Abozaid, Human Anatomy and Embryology Department, Faculty of Medicine, Minia University, Mobile: 01004065004, E-mail: samahabuzaid.eg@yahoo.com

Introduction
The infraorbital foramen (IOF) is the aperture of infraorbital canal on face. It is present in the maxillary bone bilaterally. It situated a little inferior to the infraorbital edge. It transmits the infraorbital nerve and accompanying vessels (Nanayakkara et al., 2016).
The maxillary nerve continues anteriorly as the infraorbital nerve (ION). It leaves the pterygoid fossa through the infraorbital fissure, the infraorbital groove and canal to appear anteriorly on the face at the IOF (Macedo et al., 2009).

The ION carries pure sensory fibers. Through its course in the inferior orbital canal it innervates the anterior teeth and premolar teeth and their associated gingiva through anterior superior alveolar nerve and middle superior alveolar nerve respectively. Its terminal branches supply skin and mucous membrane of midface. As it is related to vital anatomical structures as the nose, the orbit and oral cavity so during maxillofacial or nerve block procedures, proper localization of the foramina is substantial (Varshney and Sharma, 2013).

GPF is located in the posterolateral part of hard palate. The palatine canal connects the pterygopalatine fossa superiorly with GPF inferiorly. It transmits the greater palatine nerve (GPN) and accompanying vessels. The GPN is a branch from maxillary nerve (Standring et al., 2005).

As the GPN appears in the oral cavity it passes anteriorly within a well-defined groove between the hard palate and the alveolar process to supply the hard palate and gingiva as far as the 1st premolar. Greater palatine nerve block through the GPC was described by (Piagokou et al., 2012) which is superior to tuberosity approach as the latter may injure the pterygoid venous plexus with subsequent hematoma (Hawkins and Isen, 1998).
The mandibular foramen (MF) is irregular outlined aperure present a little superior to the middle of the inner surface of mandibular ramus. It allows passage of the inferior alveolar nerve and vessels through it. As the nerve traverses the canal it divides into mental and incisive branches to supply the mandibular teeth (Yu et al., 2015). Inferior alveolar nerve block is a common local anesthetic procedure used by dentists (Shah et al., 2013). Faulty localization of MF increases the failure rate and may cause injury to the neurovascular bundle (Oguz and Bozkir, 2002).

Limited information about proper anatomical site of these key foramina and the appropriate length of needle penetration into pterygopalatine fossa in Egyptian population had motivated us to do the present study using Egyptian adult dry skulls and mandibles as a reference. The aim of the present study is to determine the proper anatomical site of these foramina in relation to different nearby anatomical landmarks and the suitable length of needle penetration into pterygopalatine fossa to avoid complications.

Material and Methods (fig. 1, 2, 3)

This study was conducted on 50 dry adult Egyptian skulls and 50 dry mandibles (29 male & 21 female). They were obtained from Anatomy department of El Minia medical college. All the skulls examined had fully erupted third molar teeth bilaterally, to ensure adult age (above 18 years) (Tuteja et al., 2012). Sex differences were indicated by gross anatomical features as males have prominence of superciliary arch, glabella and mastoid process followed by more roughness of area for muscle insertions (Ajanović et al., 2016). Sex discrimination for mandible is by the rocker-shaped appearance in males and straight inferior border of the mandible in females. The shape of the chin in most males was mostly bilobate and square whereas female mandible was mostly pointed chin (Nagaraj et al., 2016). Bone with Deformity, trauma, major pathology, that of children and those with confusion of sex were excluded

Morphoscopic examination

The IOF, the GPC and MF were examined bilaterally by naked eye for their appearance (shape), bilateral similarity (symmetricity) and the presence or absence of accessory foramina and their number if present.

Morphometric examination

For anatomical localization of the studied foramina the following variables were measured on both sides with sliding Vernier caliper of 0.1 mm accuracy. The distances between the studied foramina and nearby anatomical landmarks were recorded. Each variable was taken twice by the same examiner and if a non-similar values obtained; their mean value was calculated and recorded.

Table I: Definitions of the different variables measured in the present study

Variables	Definition
For IOF	
IOF-MAXILLA	The vertical distance from the superior edge of IOF to the maxillary alveolar ridge, parallel to sagittal plane and perpendicular to Frankfurt plane
IOF-IOM	The vertical distance from the highest point of the IOF to the IOM, parallel to sagittal plane and perpendicular to Frankfurt plane
Vertical dimensions of IOF	Maximum vertical diameter of IOF
Horizontal dimensions of IOF	Maximum horizontal diameter of IOF
IOF-ANS	The distance between the center of IOF and the anterior nasal spine (ANS) along transverse plane
IOF-NASION	The distance between the center of IOF and the nasion along transverse plane
IOF-EAM	The distance between the IOF and the anterior margin of external acoustic meatus in a Frankfurt plane by flexible inelastic tape along zygomatic arch. To the best of our knowledge this is the first time to localize the distance between EAM and IOF
For GPC	
GPF-Medline	The shortest horizontal distance from center of GPF to intermaxillary suture
GPF-M3	The shortest distance from center of GPF to 3rd maxillary molar teeth
GPF (DEPTH)	A25-gauge, 30 mm needle was used. The shaft was bent at 45^{o} angle next to the needle hub. An elastic stopper was inserted into the needle. Then, the needle was inserted through the GPF and once the needle tip is seen in the pterygopalatine fossa the elastic stopper was set at the level of the hard palate and the length of the needle penetration was measured
For MF	
AB-MF	Horizontal distance from the midway point of anterior edge of Mandibular foramen to the nearest point on the anterior border of the ramus of mandible
PB-MF	Horizontal distance from the midway point of posterior edge of Mandibular foramen to the nearest point on the posterior border of the ramus of mandible
AB-PB	Horizontal breadth of the ramus from anterior to posterior border
MF-MN	Vertical distance from the lowest point of mandibular notch to the inferior edge of mandibular foramen
MF-MB	Vertical distance from inferior edge of Mandibular foramen to the base of the mandible
3rd molar MF	distance from the midway point of third molar tooth to anterior edge of Mandibular foramen

Fig. (1): showing measured variables of IOF to nearby anatomical landmarks.

Fig. (2): showing distance between GPF and intermaxillary suture and the method of needle penetration into GPC

Fig. (3): showing measured variables of MF to nearby anatomical landmarks.

Fig. (4): showing the methodology of measuring the distance between the IOF and the anterior margin of external acoustic meatus using flexible inelastic tape along zygomatic arch.

Statistical Analysis

The data were analyzed using SPSS statistical package version 20. Mean and standard deviations (mean± SD) and Student-*t* test was done to establish the presence of significant sex or side differences. *P*-value of < 0.05 was considered statistically significant.

Results

Morphoscopic study (fig 4)

For IOF

The shape of the foramina varies from oval (68%), round (30%) and triangular (2%)

The accessory foramina were reported unilaterally in 10% of studied foramina with right side predominance (80%). No skull with bilateral accessory foramina was present.

For GPC

The shape of the foramina varies from oval (64%) and round (36%).Sides of the same skull may show different shapes of the foramina.

The accessory foramina were reported unilaterally in 6% of studied foramina with right side predominance (66.6%). No skull with bilateral accessory foramina was present.

For MF

The shape of MF was irregular.

Single accessory MF was found unilaterally in 25 mandibles with left side predominance (22 mandibles). Double accessory MF was found unilaterally in 21 mandibles with left side predominance (19 mandibles). Bilateral single accessory was 3 and bilateral double accessory was one (table II).

Table II: Number and percentage of accessory MF according to side and laterality

Accessory MF	No (%)
Right sided single accessory MF	3 (6%)
Right sided double accessory MF	2 (4%)
Left sided single accessory MF	22(44%)
Left sided double accessory MF	19(38%)
Bilateral single accessory MF	3(6%)
Bilateral double accessory MF	1(2%)

Fig. (5): showing accessory foramina of IOF, GPF and MF.

Morphometric study

For sex difference (Table III)

For IOF

Statistical analysis of the IOF distances from nearby anatomical structures for both sexes revealed no significant difference in all studied parameters.

For GPC

Statistical analysis of the GPC distances from nearby anatomical structures for both sexes revealed no significant difference in all studied parameters.

For MF

Statistical analysis of the MF distances from nearby anatomical structures for both sexes revealed no significant difference in all studied parameters.

Table III: student T-test of the studied foramina from nearby anatomical structures for both sexes

Parameters	Males		Females		*P- value*	
	Rt **(n=29)** Mean±SD	Lt **(n=29)** Mean±SD	Rt **(n=21)** Mean±SD	Lt **(n=21)** Mean±SD	Rt	Lt
IOF						
IOF-IOM	7.27±1.52	7.14±0.94	7.09±1.19	6.89±0.87	0.2602	0.7301
IOF-MAXILLA	28.34±4.79	30.12±3.142	27.64±4.11	28.19±2.94	0.4832	0.7694
Vertical IOF	3.58±0.82	3.69±0.64	3.39±0.56	3.42±0.8	0.08133	0.2719
Horizontal IOF	4.34±1.91	4.83±1.29	4.26±1.32	4.69±1.51	0.09100	0.4349
IOF-ANS	32.34±1.47	31.89±2.54	31.68±1.96	30.59±3.11	0.1583	0.3180
IOF-NASION	45.12±2.91	45.04±2.48	44.69±2.16	44.58±2.67	0.1710	0.7060
IOF-EAM	10.06±0.12	9.8±0.19	10.01±0.1	9.71±0.2	0.4024	0.7880
GPF						
GPF-Medline	14.29±2.71	14.54±1.96	14.02±2.63	13.94±2.05	0.9046	0.8117
GPF-3rd M3	10.54±1.19	9.89±1.78	10.17±1.71	9.41±1.19	0.07634	0.06616
GPF (DEPTH)	18.65±2.31	18.62±1.76	18.49±2.05	18.28±1.56	0.5870	0.5870
MF						
AB-MF	17.91±3.54	18.91±1.98	17.75±3.41	18.57±1.72	0.8766	0.5199
PB-MF	11.28±1.84	11.19±1.37	10.98±1.67	10.82±1.58	0.6618	0.4783
AB-PB	31.34±1.49	30.85±3.47	30.94±1.87	30.17±3.51	0.2635	0.9379
FORAMEN WIDTH	3.1±0.81	3.24±1.24	2.86±0.92	3.08±0.98	0.5252	0.4869
MF-MN	22.51±2.14	20.58±3.47	22.34±2.05	20.13±3.37	0.8558	0.9073
MF-MB	28.64±3.17	28.29±2.65	28.21±3.51	27.65±2.17	0.6083	0.3583
3RD molar MF	25.1±4.97	26.47±4.14	24.48±5.31	26.12±4.06	0.7335	0.9442

Rt=right Lt=left M=mean SD= standard deviation *=significance (p<0.05)

For side difference (Table IV)

For IOF

Statistical analysis of the IOF distances from nearby anatomical structures for both sides revealed that the left IOF-Maxilla and vertical diameter of IOF were higher than the right significantly ($p < 0.05$) for the other parameters there were no significant difference.

For GPC

Statistical analysis of the GPF distance from nearby anatomical structures for both sides revealed that there was no significant difference in the studied parameters.

For MF

Statistical analysis of the MF distance from nearby anatomical structures for both sides revealed that AB-PB and MF-MN were greater in right side than those of left significantly ($p < 0.05$) except left AB-MF and left foramen width which is significantly higher than right but for PB-MF, MF-MB and 3rd molar MF there were no significant side difference.

Table III: student T-test of the studied foramina from nearby anatomical structures for both sides

Parameters	Right foramina of both sexes Mean± SD (50)	Left foramina of both sexes Mean± SD (50)	*P- value*
			IOF
IOF-IOM	7±1.16	7±0.899	0.08
IOF-MAXILLA	28.14±4.49	29.71±3.199	0.02*
Vertical IOF	3.43±0.79	3.57±0.54	0.008*
Horizontal IOF	4.29±1.25	4.71±1.38	0.5
IOF-ANS	32±2.16	31.6±2.23	0.84
IOF-NASION	44.9±2.85	44.86±3.48	0.17
IOF-EAM	9.93±0.06	9.86±0.09	0.4126
			GPF
GPF-Medline	14.1±2.41	14.3±2.43	0.95
GPF-3rd M3	10.29±1.38	9.71±1.25	0.5
GPF (DEPTH)	18.57±2.15	18.43±1.99	0.58
			MF
AB-MF	17.8±3.4	18.8±2.05	0.0004*
PB-MF	11.2±1.79	11±1.41	0.1033
AB-PB	31.2±1.79	30.6±3.85	0.00000*
FORAMEN WIDTH	3±0.71	3.2±1.1	0.00268*
MF-MN	22.4±2.3	20.4±3.36	0.00916*
MF-MB	28.4±3.78	28.2±2.95	0.08513
3RD molar MF	24.8±5.45	26.2±4.66	0.2754

Rt=right Lt=left M=mean SD= standard deviation *=significance ($p<0.05$)

Discussion

Knowledge of the anatomical criteria of these key foramina is of value for proper practice with less failure rate and complications (Singh, 2011).

In the present study the prominent superior border of IOF was used as reference point for measuring IOF-IOM and IOF-Maxilla as it can be identified easily.

Regarding the sex difference in IOF there was no significant difference for all measured dimensions in the present study however, (Oliveira et al., 2016) reported significant sex difference in Lt vertical dimension of IOF, Rt and Lt horizontal dimension and Rt and Lt IOF-ANS. This insignificant difference in the present study may be due to that sex determination is diagnosed by anatomical criteria not a well-known sex. Also the sample in the present study was of adult age with wide range and not exact age is known.

The mean vertical dimension of IOF of right side of skull was 3.43±0.79 mm, and that of left was 3.57±0.54 mm with significant difference so caution should be taken during nerve block as there is side difference in vertical dimension reported in this study. The horizontal dimension value was greater than the vertical one with no significant difference. This highlights the importance of proper localization of foramen in a vertical plane as there is narrow distance, side difference and nearby orbit. On the other hand other study reported no significant side difference in IOF dimensions (Varshney and Sharma, 2013).

The mean distance between the IOF and IOM was 7±1.16 mm on right side of skull and 7±0.899 mm on left side with no significant difference (p=0.08). Lower values of 6.46±1.57 mm and 6.47±1.72 mm for right and left side respectively with no significant difference were reported by

(Bharti and Puranik, 2013). Others reported higher values on the right and left sides of 7.73 ± 1.23 mm and 7.81 ± 1.45 mm with significant difference (P = 0.01) respectively (Varshney and Sharma, 2013).
Wide variability in the values of the mean distance between the IOF and IOM (3-10 mm) had been recorded in several studies (Hindy, Abdel-Raouf , 1993 ; McQueen et al., 1995 and Canan et al., 1999). This leads to the need for safety value determination to avoid injury to nearby orbit (Kazkayasi et al., 2001).

Table V. Studies comparing locations of IOF-IOM of some populations

Studies	Parameters(mm) mean±SD	N^o of skulls
HindyandAbdel-Raouf(1993)	6.1 ± 2.4	(i)30adultskulls (ii)15adult human Egyptian cadavers,
Kazkayasi et al., 2001	7.19	Cadavers
Singh (2011)	6.16	55 Indian skulls
Aggarwal et al(2015)	6.32	67dry adult skulls
Present study	7.14 ± 0.95 for both sides	50 dry Egyptian skulls

The difference between different studies may be explained due to race difference, sample type; dry skulls, cadavers and radiographs and also it may be due to difference in anatomical reference landmarks also (Varshney and Sharma, 2013) reported that morphometric data of the IOF show wide racial variations.

The mean distance between the IOF and Maxilla was 28.14±4.49 mm on right side of skull and 29.71±3.199 mm on left side (p=0.02). This statistical difference between right and left side add to the importance of proper localization of foramen in a vertical plane. Lower values were reported by (Varshney and Sharma, 2013).

In the present study the position of IOF in relation to IOM, ANS and Nasion showed no significant side difference. However, (Nanayakkara et al., 2016) reported significant difference in these values and suggest that the proper anatomical site of the IOF is sometimes asymmetry even in same person.

The accessory IOF were reported unilaterally in 10% of studied foramina with right side predominance (80%). Wide variations were observed in accessory IOF among different sub-groups with values ranging from 1% to 18.2% (Berry, 1975; Kazkayasi et al., 2001 and Boopathi et al., 2010).

The mean distance between the GPF and Medline was 14.1±2.41mm on right side and 14.3±2.43 mm on left side (p=0.95). These values are comparable to those reported in Indian skulls as their GPF is located 14–15mm from the intermaxillary suture (Ashwini and Jaishree, 2014).

The mean distance between the GPF and 3rd molar teeth was 10.29±1.38 mm on right side and 9.71±1.25 mm (p=0.5). Higher values 11.3 and 11.4 mm for right and left sides respectively were reported by (Tomaszewska et al., 2014) with no significant difference

The mean distance of depth of GPC was 18.57±2.15 on right side of skull and 18.43±1.99 on left side with no statistical difference (p=0.58). Also (Douglas and Wormald, 2006) reported near values of 17.56±2.88 and 17.25±2.51 for right and left sides respectively.
This depth of GPC was significantly smaller than the distance between the IOF and the maxilla.

The proper anatomical site of the mandibular foramen is important to avoid injury to the inferior alveolar nerve which is liable to injury during these practices. (Daw et al., 1999) have reported very wide variation in the location of mandibular foramen from Non-Asian hemi mandibles and the proper location of the mandibular foramen is important in executing a proper sagittal split of the mandibular ramus.

In the present study there was no statistical sex difference in the measured dimensions of the ramus of mandible however a significant difference between the distance from the center of the mandibular foramen to the anterior border and mandibular notch was reported by (Nagaraj et al., 2016).

In the present study the mean distance from anterior border of mandibular ramus to anterior margin of mandibular foramen (AB-MF) was 17.8±3.4 mm on right side and 18.8±2.05 mm on left side with significant difference. Different studies reported different values as Ennes and Medeiros (2009) reported AB-MF value as low as 9.4±2.03 on the right side others as Prado et al. (2010) reported value of 19.2±3.6 for the same parameter.

In the present study (PB-MF) was 11.2±1.79mm on right side and 11±1.41mm on left side, (MF-MN) was 22.4±2.3 mm on right side and 20.4±3.36mm on left side and (MF-MB) was 28.4±3.78mm on right side 28.2±2.95mm on left side. These values are comparable with the those reported by (Shalini et al., 2016) in his study in south India except for MF-MB value which was higher in the present study than those reported by (Shalini et al., 2016) who reported values of 22.33±3.32mm and 25.35±4.5mm for right and left side respectively). However Mbajiorgu (2000) on his study on adult black Zimbabwean reported value of 28.44±0.65mm for MF-MB which is comparable to the present study.

For 3rd molar MF parameter the values reported in the present study was 24.8±5.45 mm and 26.2±4.66mm for right and left side respectively (p=0.2754). Lower values as 15mm on right side and 18mm on left side were recorded by (Varma et al., 2011) and comparable mean value of 25mm was reported by (Kilarkaje et al., 2005). Several studies have reported a significant variable morphology in the anatomy of mandible among different racial groups—Caucasoid, Mongoloid, and Negroid (Neiva et al., 2004; Komar and Lathrop, 2006).

In the present study there is significant side difference in AB-MF, AB-PB, Foramen width, MF-MN This is in agree with Nicholson (1985) who reported variation of the two mandibular rami in the same person, so standardization of the foramen is not easy. However, there was no significant difference in PB-MF, MF-MB and 3rd – MF. Also in a study done by (Shalini et al., 2016) no statistically significant difference reported between the values obtained on the right and left sides (P>0.05).

The embryological explanation of occurence of accessory mandibular foramen is development 3 inferior alveolar nerves, innervating each of the 3 groups of mandibular teeth, all the 3 nerves unite and a single inferior alveolar nerve is formed. The incomplete union of these nerves leads to the persistence of accessory mandibular canals (Chávez-Lomeli et al., 1996)

The accessory foramina have potential role in neurovascular transmission and applied anatomy (Longoni et al., 2007). As acessory foramina explain the cause of failure during regional anesthesia (Cutright et al., 2003) and the caution that should be taken to avoid partial or complete nerve damage (Aziz et al., 2000).

This highlights the importance of studying frequency and position of accessory foramen to reduce anesthetic and surgical complications. In the present study the occurrence of single accessory MF was 50% unilaterally with left side predominance. The statistically significant left side predominance may be due to chance and until now there is no explanation for it.

Percentage of single accessory MF foramina varies from as low as 13.72% (Shalini et al., 2016) and as high as 29.2% (Padmavathi et al., 2014)

Conclusion

Standard localization of the studied foramina until now is difficult due to wide anatomical variation in shape, dimensions, relation to nearby anatomical structures and accessory foramina not only within same population even within same individual.

Limitation of the study

This study had limitation of having small sample size, thus a larger sample is required to yield more authoritative results for Egyptian population. Also demographic characteristics that affect growth and development of various body parts were unknown, such as, exact age, nutritional status, occupation, etc.

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دراسة مورفومترية للثقب الرئيسية فى عمليات الوجه والفكين فى الجماجم الجافة والفك السفلى الجاف فى السكان المصريين

سماح محمد محمود أبوزيد - مدحت عطا صلاح
قسم التشريح *، كلية الطب، جامعة المنيا

الملخص العربى

إن الثقبة المدارية السفلية ، الثقبة الحنكية الكبرى وثقب الفك السفلي هي ثقوب مهمة تستخدم في العمليات الجراحية المختلفة. إن الهدف من هذه الدراسة هو تحديد الموقع التشريحي لهذه الثقوب بالنسبة لعلامات تشريحية قريبة منها والطول المناسب لاختراق الإبرة في الحفرة الجناحية. وقد تم اختيار ٥٠ عظمة جمجمة و٥٠ عظمة فك جافة مكتملة التعظم من كلا الجنسين (٢٩ ذكر و ٢١ أنثى) لاجراء قياسات عليهم من السكان المصريين. تم تحديد الجنس باستخدام معايير تشريحية . تم فحص جميع الثقوب من حيث الشكل ، والتناظر ، والثقوب الثانوية. وقد اتخذت جميع القياسات على كلا الجانبين باستخدام الفرجار. وتم اختبار الاختلاف الجنسي و الجانبي وتحليل نتائج القياسات إحصائيا. ، وقد اسفرت النتائج عن أن هناك اختلاف فى بعض القياسات محط الدراسة بين الجانب الأيمن والأيسر لكل من الثقبة المدارية السفلية و ثقب الفك السفلى ولم يوجد أى اختلاف احصائى بالنسبة للثقبة الحنكية الكبرى وبالنسبة لفرق الجنس لم تكن هناك فروق ذات دلالة إحصائية فى جميع القياست محل الدراسة

نستخلص مما سبق ان هذا البحث يسلط الضوء على ان تحديد موقع هذه الثقوب ممكن ومهم في جراحة الوجه والفكين والتخدير الموضعي لتقليل معدل الفشل ومنع المضاعفات.

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