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Morphometric Evaluation of the Superior Orbital Fissure

Evaluación Morfométrica de la Fisura Orbitaria Superior

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SUMMARY: The superior orbital fissure, the connection of the orbit with the middle cranial fossa, is contained between the greater wing, the lesser wing and the lateral side of the body of the sphenoid bone. Its clinical significance is due to the nerves and blood vessels passing through, as well as the possibility of microsurgical access to the middle cranial fossa and the cavernous sinus. The aim of this study was to determine the morphometric parameters of the superior orbital fissure in Serbian population, and to determine whether there was significant difference between the left and right side of the body and between sexes. The sample consisted of 30 human skulls (15 female and 15 male) from the osteological collection of the Department of Anatomy of the Faculty of Medicine, University of Novi Sad. The photographs of the superior orbital fissures were taken, and had been inserted in ImageJ 1.48v software. We measured their length and width, and defined their shape. The average length of the superior orbital fissure in our sample was 12.47 mm, and the average fissure width was 5.36 mm. We defined ten morphological types of superior orbital fissures (I-X). Type II was the most common type (22 %), and type VI of superior orbital fissure type was the least common (2 %). The dimensions of the superior orbital fissure in our study are statistically significantly different from the values in our population previously determined by other researchers. The length of the superior orbital fissure of our sample coincides most closely with the study of the Polish population, and the average value of the fissure width is statistically significantly higher than the one in the Korean population. There is no statistically significant difference in distribution of morphological forms of superior orbital fissure in relation to sex and side of the body.

KEY WORDS: Superior orbital fissure; Morphological types; Morphometry; Human skull.

INTRODUCTION

The shape of the superior orbital fissure (SOF) is usually described as a notch or elongated pear, with the wider end facing inwards, backwards and downwards, and the narrower end or apex facing outwards, forwards and upwards (Bone & Hadley, 2005; Obradovic *et al*., 2008). However, there is a whole range of morphological forms of SOF, and its exceptional morphological variability is most often defined using a scheme of nine different morphological forms (Natori & Rhoton Jr., 1995; Shi *et al*., 2007).

The SOF is commonly divided into distinct topographical compartments. Most researchers identify only two compartments: inferomedial or inferior compartment, and superolateral or superior compartment (Shapiro & Robinson, 1967; Bergin, 1987; Morard *et al*., 1994; Govsa *et al*., 1999). Inferomedial or inferior compartment of the SOF occupies the inferolateral segment of the common tendinous ring (tendinous anulus of Zinn), while the superolateral or superior compartment of the SOF is located lateral to the common tendinous ring. The structures that pass through the common tendinous ring and the inferomedial part of the SOF are the oculomotor nerve, the nasociliary nerve, and the abducens nerve. According to Sljivic (1975), the sympathetic root of the ciliary ganglion and sometimes the inferior ophthalmic vein also pass through this area. The structures that pass through the superolateral part of the SOF, outside of the common tendinous ring, include the lacrimal nerve, the frontal nerve, the trochlear nerve, the meningeal branch of the lacrimal artery, and the superior ophthalmic vein.

Other researchers propose that the SOF can be divided into three distinct compartments: lateral, medial, and inferior (Natori & Rhoton Jr., 1994, 1995; Ettl *et al*., 1997, 2000). The lateral compartment corresponds to the superolateral part of the SOF and contains the lacrimal, frontal and trochlear nerves and the superior ophthalmic vein. The medial compartment corresponds to the common tendinous

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ring and contains the oculomotor, nasociliary and abducens nerves, as well as the sensory and sympathetic roots of the ciliary ganglion. Inferior compartment of the SOF is located below the common tendinous ring and is usually traversed by the inferior ophthalmic vein.

The morphological types and dimensions of the SOF affect the arrangement of the anatomical structures that pass through it, and therefore the planning of the surgical approach during microsurgical interventions performed in this area of the orbit. Through the SOF, one can access the middle cranial fossa and cavernous sinus.

The width, and therefore the shape of the SOF are risk factors for the occurrence of the syndrome of the same name. Superior orbital fissure syndrome (SOFS), known as Rochen-Duvigneaud syndrome, is a rare condition that encompasses the disfunction and/or injury to the anatomical structures passing through the SOF. The causes of SOFS are numerous. Craniofacial trauma is the most common cause of SOFS (Chen & Chen, 2010). Other possible causes of SOFS are infectious processes (orbital pseudotumor and Tolosa-Hunt syndrome), vascular lesions (e.g. aneurysm, carotid-cavernous shunt, cavernous sinus thrombosis, etc.), tumors (most often pituitary adenoma, meningioma and craniopharyngioma), sphenoethmoidal sinusitis (Mortada, 1961.; Lakke 1962; Ettl *et al*., 2000; Dilberovic & Kapur, 2002; Vaughan & Asbury, 2017). In addition, it is worth noting that SOFS can also be caused, albeit rarely, by neoplastic causes, such as sinonasal tumors (De Rezende Pinna *et al*., 2005). Superior orbital fissure syndrome is manifested by ophthalmoplegia, ptosis, dilation and fixation of the pupils, as well as loss of sensitivity of the upper eyelid and part of the forehead. Propagation of the process toward the orbital apex results in orbital apex syndrome, characterized by proptosis and optic nerve compression, variably accompanied by symptoms of SOFS. It is important to note that variations in the size and shape of the SOF can lead to differences in how patients present with symptoms related to orbital or cranial nerve pathologies.

Knowledge of these structures, their relationships and variations, as well as their position and orientation is a key point in the assessment, diagnosis and therapy of fractures, tumors and inflammatory processes in the area of the orbital apex, as well as in the adjacent topographic areas. Adequate presentation and description of the orbital apex is possible with the use of computerized tomography.

The importance of the topographical anatomy of SOF is reflected in the fact that surgeon can expect certain morphological types of SOF intraoperatively, and therefore the arrangement of anatomical structures that lie in a close relationship with each other. Knowing the morphological variability and variations in SOF dimensions reduces the risk of injuring anatomical structures within the SOF during surgical interventions.

MATERIAL AND METHOD

The sample for this research was taken from the collection of human skulls of the Department of Anatomy, Faculty of Medicine, University of Novi Sad. The sample consisted of 30 human skulls, 15 female and 15 male. This means that a total of 60 superior orbital fissures were measured. All of the skulls with damage to one or both SOFs were excluded from the study. The sex of each skull was assessed using the protocol for visual determination of the sex of the skull, which was modified according to Ferembach *et al*. (1980), and Buikstra *et al*. (1994). A detailed description of the skull sex determination can be found in the work of Krstonosic *et al*. (2011).

We placed the skulls in the Frankfurt plane and photographed the left and right eye sockets using a Samsung S1060 10.2 Megapixel camera (Fig. 1). All photographs were analyzed in the ImageJ 1.48v program, by measuring the length and width of the SOF three times, and their mean values were taken as the values of the SOF dimensions. All measurements were made by the same person and the measured values (expressed in millimeters) were entered in the protocol.

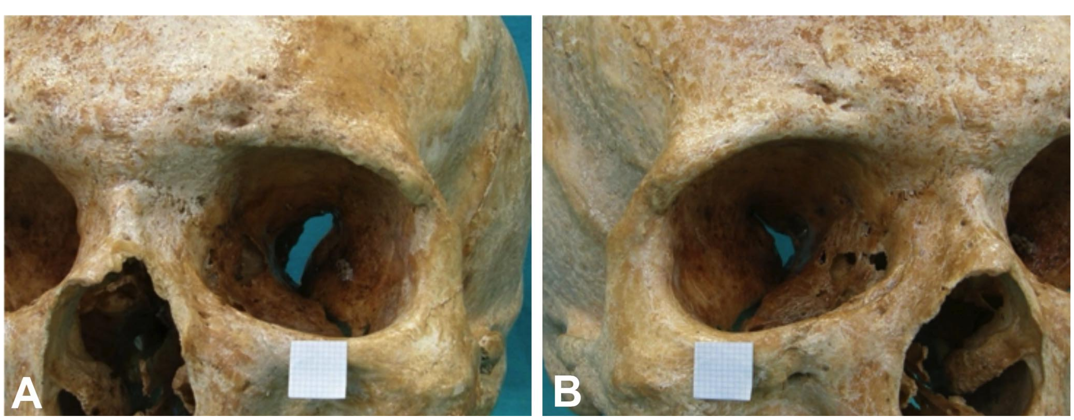

Fig. 1. Photographs of the superior orbital fissure.
A - left superior orbital fissure;
B - right superior orbital fissure.

The length of the superior orbital fissure was measured as the distance between the lowest point of its lower edge and the apex, while its width was measured as the distance between the farthest opposite points of the upper outer and upper inner edge (Fig. 2).

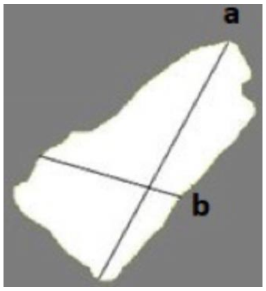

Fig. 2. Measured parameters: a - the length of the superior orbital fissure; b - the width of the superior orbital fissure.

In statistical data processing, we used absolute and relative numbers, mean, standard deviation, minimum and maximum values. A one-sample Student's t-test was used to determine whether statistically significant difference in SOF length and width between the means of our sample and the means within our population (Sljivic, 1975) exists, as well as for the comparison of the results of our study with studies conducted within other populations. In order to analyze statistical differences by sex or side of the body, Student's t-test for independent samples was used. The entire data processing was performed in the SPSS v.19 program, and the results were presented tabularly and graphically.

RESULTS

By analyzing our sample of 30 human skulls, 15 of which were female and 15 male, we obtained the following results: the average value of the length of the SOF in our sample was 12.47 mm, while the average value of the width of the SOF was 5.36 mm (Table I). There was a statistically significant difference between the average values of length and width of the SOF and their supposed values in our population (Sljivic, 1975).

Table I. Values of morphometric parameters of the SOF in our sample.

Morphometric parameter	x±SD	Min	Max	P
Length	12.47±2.87	5.73	19.48	0.000**
Width	5.36±1.62	2.79	9.32	0.000**

**p<0.05

Table II shows the mean values of the length and width of the left and right SOF, which show that there are no statistically significant differences in SOF dimensions in relation to the side of the body. Further analysis revealed that the SOF dimensions between the sides of the body do not statistically significantly differ in relation to sex.

Table II. Values of morphometric parameters of left and right superior orbital fissures.

Morphometric parameter	Side	x±SD	Min	Max	p
Length	Right	13.19±2.82	5.73	18.01	0.674
	Left	13.89±2.93	6.34	19.48	
Width	Right	5.93±1.55	2.79	8.34	0.988
	Left	6.02±1.71	3.01	9.32	

Average values of SOF length are slightly higher in skulls with female characteristics, while mean values of SOF width are approximately equal in both sexes (Table III). After processing the data, it was observed that there is no statistically significant difference in length (p=0.801) or width (p=0.868) of the SOF between sexes.

Table III. Values of morphometric parameters of the superior orbital fissure of male and female skulls.

Morphometric parameter	Sex	x±SD	Min	Max	p
Length	Female	13.66 ±2.95	5.73	18.01	0.801
	Male	13.43 ±2.84	6.34	19.47	
Width	Female	5.96 ±1.68	2.79	9.07	0.868
	Male	5.99 ±1.59	3.25	9.32	

By further morphological analysis of the SOF on the skulls in our sample, we observed the existence of ten different morphological types of the SOF (Fig. 3).

Fig. 3. Morphological types of the superior orbital fissure (I-X).

The frequency of each morphological type is shown in Figure 4. In our sample, the most common type is type II (22 % of cases), and the least common type is type VI (2 % of cases).

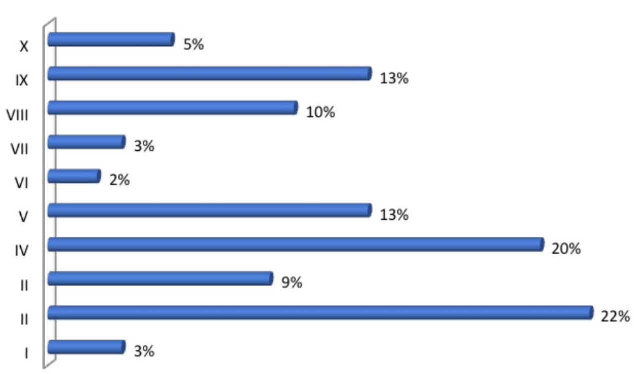

Fig. 4. The prevalence of morphological types of the superior orbital fissure.

The prevalence of morphological types of the SOF in relation to gender is close to the limit of statistical significance (p=0.052). The most common type of SOF in skulls with female characteristics is type IV (26.67 %), and in those with male characteristics, type V (23.33 %).

In relation to the side of the body, there is no statistically significant difference in the prevalence of morphological types of SOF (p=0.667).

DISCUSSION

The measured average values in our sample (SOF width of 5.36 mm and SOF length of 12.47 mm) were lower than the previously recorded average values ??within our population, namely the width of the SOF in our population ranges from 8 to 10 mm, while the length of the SOF, according to available literature, ranges from 18 to 20 mm (Sljivic, 1975). The difference between average values in our sample and the recorded values in our population was statistically significant for both width and length of SOF (p<0.05). In the available literature on the measurement of SOF in the Serbian population, there is no explanation of how the dimensions of SOF were measured, and it is possible that the statistically significant difference can be explained by the difference in research methodology. Also, since the skulls from our sample are mostly of unknown origin, it is possible that there are ethnic factors that influence this statistically significant difference in SOF dimensions between our sample and values within our population.

In their study, Park & Kim (2017) stated that in the Korean population, the average width of the SOF is about 3.70 mm, with no statistically significant difference in relation to gender and side of the body. Fujiwara *et al*. (2009) showed that there is no statistically significant difference between the results of measuring the dimensions of SOF using computed tomography and directly on cadavers. The results of the mentioned Korean study, especially the lower SOF width, can only be interpreted as a consequence of the racial difference in morphology compared to our European population.

Reymond *et al*. (2008), in their research within the Polish population, did not find a statistically significant difference between the size of the SOF in relation to gender, side of the body or morphological type of SOF. They described nine morphological forms of the SOF, which were divided into two types - a (A-E) and b (F-I), with different mean lengths of the SOF (a - 17.47 mm, b - 12.48 mm). Our most abundant morphological form of the SOF is type II, which could morphologically correspond to the subgroup "b" according to Raymond *et al*. (2008), and that also coincides with the similar average values of the SOF length in their study and ours. These results could explain the difference in the average values of the SOF length in the statements of Sljivic (1975) and our results - that different morphological types conditioned different dimensions of the SOF between two samples of the same population.

Shapiro & Janzen (1960) defined six different morphological forms of SOF, to which Sharma *et al*. (1988), added three new morphological forms, so that the SOF morphological scale with a total of nine types was created. The results of the study by Sharma *et al*. (1988), as well as by Govsa *et al*. (1999), show that in their samples of the Indian and Turkish population, type VI is the most common, while Shapiro & Janzen (1960), analyzing the skulls of the American population, showed that type I of the SOF is the most common (40 % of cases).

By comparing our results with the results of the study by Govsa *et al*. (1999), we can observe the morphological similarity between Govsa's dominant type VI, and type III in our sample. Also, in the Turkish population, the research was carried out by Magden *et al*. (1995), in whose study type IX was the most prevalent (38.8 % of cases) without a clear morphological similarity to any type of the SOF from our study.

The major limitations of our study are the small sample size and the unknown origin of the skulls. Due to the clinical significance of understanding the shape and size of the SOF, the main task for future research is to increase the sample size and to explore the results of available studies in more detail.

CONCLUSIONS

We believe that the difference in SOF dimensions between populations is primarily caused by the morphological variability of SOF. The anatomical variability of SOF is of great clinical importance, due to the possible occurrence of superior orbital fissure syndrome due to maxillofacial trauma, infection, or tumor. SOF represents the communication between the eye socket and the middle cranial fossa, and understanding its variations is crucial in the microsurgical approach to the middle cranial fossa and cavernous sinus.

From this research it can be concluded that the most common forms of the SOF were type II (22 % of cases) and type IV (20 % of cases). In skulls with female characteristics, type IV was the most common, and in those with male characteristics, type V. The average SOF length in our sample was 12.47 mm, while the average SOF width was 5.36 mm. Our results show that the length and width of the SOF do not statistically significantly differ in relation to sex, or in relation to the side of the body.

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RESUMEN: La fisura orbitaria superior, la conexión de la órbita con la fosa craneal media, está contenida entre el ala mayor, el ala menor y el lado lateral del cuerpo del hueso esfenoides. Su importancia clínica se debe a los nervios y vasos sanguíneos que pasan a través de ella, así como a la posibilidad de acceso microquirúrgico a la fosa craneal media y al seno cavernoso. El objetivo de este estudio fue determinar los parámetros morfométricos de la fisura orbitaria superior en la población serbia y determinar si existía una diferencia significativa entre el lado izquierdo y derecho del cuerpo y entre los sexos. La muestra consistió en 30 cráneos humanos (15 femeninos y 15 masculinos) de la colección osteológica del Departamento de Anatomía de la Facultad de Medicina de la Universidad de Novi Sad. Se tomaron fotografías de las fisuras orbitarias superiores y se insertaron en el software ImageJ 1.48v. Medimos su longitud y ancho y definimos su forma. La longitud promedio de la fisura orbitaria superior en nuestra muestra fue de 12,47 mm y el ancho promedio de la fisura fue de 5,36 mm. Definimos diez tipos morfológicos de fisuras orbitarias superiores (I-X). El tipo II fue el tipo más común (22 %) y el tipo VI de fisura orbitaria superior fue el menos común (2 %). Las dimensiones de la fisura orbitaria superior en nuestro estudio son estadísticamente significativas diferentes de los valores en nuestra población previamente determinados por otros investigadores. La longitud de la fisura orbitaria superior de nuestra muestra coincide más estrechamente con el estudio de la población polaca, y el valor promedio de la anchura de la fisura es estadísticamente significativa mayor que el de la población coreana. No hay diferencia estadísticamente significativa en la distribución de las formas morfológicas de la fisura orbitaria superior en relación con el sexo y el lado del cuerpo.

PALABRAS CLAVE: Fisura orbitaria superior; Tipos morfológicos; Morfometría; Cráneo humano.

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