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Angle Evaluation of Possible Routes that Can Be Used to Reach the Foramen Ovale in the Anterior Approach

Evaluación Angular de Posibles Rutas que se Pueden Utilizar para Alcanzar el Foramen Oval en el Abordaje Anterior

Sinan Bakirci & Rabia Selin Yayla

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SUMMARY: For the treatment of trigeminal neuralgia, the foramen ovale is reached by entering the cheek with a needle. Thermocoagulation is performed with balloon compression, administration of alcohol or radiofrequency. Apart from the classical method, it is theoretically possible to reach the foramen ovale through the mouth with the anterior approach. In our study, it was aimed to examine horizontally and vertically the angular values that must be given to the needle to reach the foramen ovale in the anterior approach. Three landmark points were determined on both right and left sides of 25 dry skulls. A rod was inserted starting from these landmark points and passing through the center of the foramen ovale. The vertical and horizontal angular values of this bar were measured. For each foramen ovale, 3 vertical angles, 3 horizontal angles and 4 distance measurements were made. There was a significant difference between the right and left sides in terms of horizontal angular values. Average values of horizontal angles (in degrees); on the right, 7.29 for H1, 12.15 for H2, 32.29 for H3; 1.26 for H1, 9.46 for H2, and 30.56 for H3 on the left side ($p<0.005$). The angle value was measured as 0 or negative value in 5 (20 %) of the H1 angle measurements made on the right side and 14 (56 %) on the left side. The H2 angle value was found to be smaller than the H1 angle in the skull 2 (8 %) on the right and 3 (12 %) on the left. There was no difference between the right and left sides in terms of vertical angular values. A significant difference was found between the right and left sides in the D1, D2, D4 distances ($p<0.005$). Six important anatomical features affecting angular values were encountered.

KEY WORDS: Foramen ovale; Rhizotomy; Angular values; Anterior approach.

INTRODUCTION

Foramen ovale is a hole in the sphenoid bone, varying in size from 4 to 8 mm in length and 3-5 mm in width. It has been shown in the literature that it can be in different forms. In addition to the oval type, there are a few studies reporting triangular, almond and semilunar types (Patil *et al*., 2013; Gupta & Gupta, 2012; Natsis *et al*., 2018; Chanda *et al*., 2020; Kastamoni *et al*., 2021). The mandibular nerve, a branch of the trigeminal nerve, passes through the foramen ovale. Just above this hole is the trigeminal ganglion. In the treatment of patients suffering from trigeminal neuralgia, this ganglion may sometimes need to be treated percutaneously. Several accepted landmarks have been identified over the years for the success of percutaneous intervention. One of these landmarks is the zygomatic point, where the straight line passing through the axis of the right and left foramen ovale intersects the zygomaticus arch. Also, the zygomatic point is located approximately 3 cm anterior to the external acoustic meatus. There are radiological studies reporting this distance as 2.5 cm (Hwang *et al*., 2005). Another landmark point is located on the cheek, 3 cm behind the corner of the mouth. The final landmark is the medial side of the patient's pupil. Hartel made the first definition of cheek approach to the foramen ovale in 1914 (Gerber, 1994; Gusmão *et al*., 2003). In clinical practice, based on these three landmark points, the foramen ovale is reached percutaneously by piercing the cheek. For this procedure the neurosurgical assistant must be well trained. It is therefore recommended that silicone models be used for training (Zdilla *et al*., 2019). In our study, different from the classical approach, certain landmark points were determined in the dry skulls to reach the foramen ovale from the anterior side without piercing the cheek. It was aimed to enter the foramen ovale from these points, to reveal the vertical and horizontal angular values of the traces obtained, and to determine the individual anatomical variables that affect these angular values and make hand practice difficult.

Izmir Katip Celebi University, School of Medicine, Department of Anatomy, Izmir Turkey.

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MATERIAL & METHOD

The study was carried out on 25 dry skulls belonging to the bone collection in the Anatomy Laboratory. Skulls with damaged skull base, foramen ovale and crista zygomaticoalveolaris were excluded from the study. Three landmark points were identified. Colored dough was glued to these spots. It was tested by means of a stick whether it could be entered into the foramen ovale from these points. Later, lateral and superior photographs were taken of the skulls (with Canon 800d Camera). In the shots from above, the photograph was taken by adjusting the camera focus point according to the foramen ovale to be measured. In lateral shots, the Zygion point is set as the focus of the camera. Angular values in the vertical and horizontal planes were measured using the Image-J program on the images obtained. Before photographing the skulls, the skulls were fixed on a table (with play dough) by inverting them for standardization (Fig. 1a). The sagittal and transverse slope of the skull base, which would affect the angular values in the photographs taken, was eliminated using a spirit level (Fig. 1b). For measurement standardization, a millimetric ruler was placed in the same plane with the skull base (Fig. 1c).

In the study, 3 horizontal angles (H1, H2, H3) and 3 vertical angles (V1, V2, V3) were measured for each foramen ovale. Starting landmark points of the axes for angle measurements; 1-The lateral edge of the juga alveolaria of the third molar tooth in the maxilla, 2-The medial-lower edge of the crista zygomaticoalveolaris at the level of the first molar tooth, 3-the most lateral-lower edge of the crista zygomaticoalveolaris. (Figs. 2a,b).

In the study, the distance of the foramen ovale to the four points was also measured. These distances are; D1-distance to the skull midline, D2-distance to the zygomatic arch, D3-distance to the posterior margin of the third molar tooth, D4-distance between the sagittal axis passing through the lateral edge of the juga alveolaria and the sagittal axis passing through the midpoint of the foramen ovale (Fig. 2c). The term right and left sides were used according to the anatomical position of the skull (not according to the skull base image).

Ethics approval and consent to participate. The approval of the ethics committee of the study was given by the "Non-Invasive Clinical Research Ethics Committee of Izmir Katip Celebi University Faculty of Medicine" with the decision numbered 20.01.2022/0005.

Statistical analysis. Made with IBM SPSS 26. Descriptive statistical analysis (median, minimum, maximum, standard deviation, mean value) was performed. The distribution of

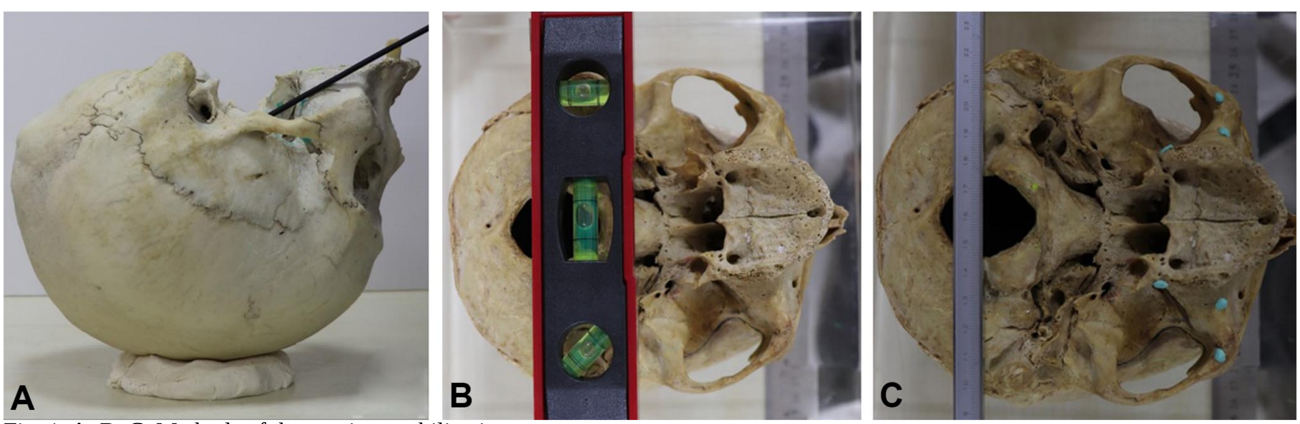

Fig. 1. A, B, C. Methods of the cranium stabilization.

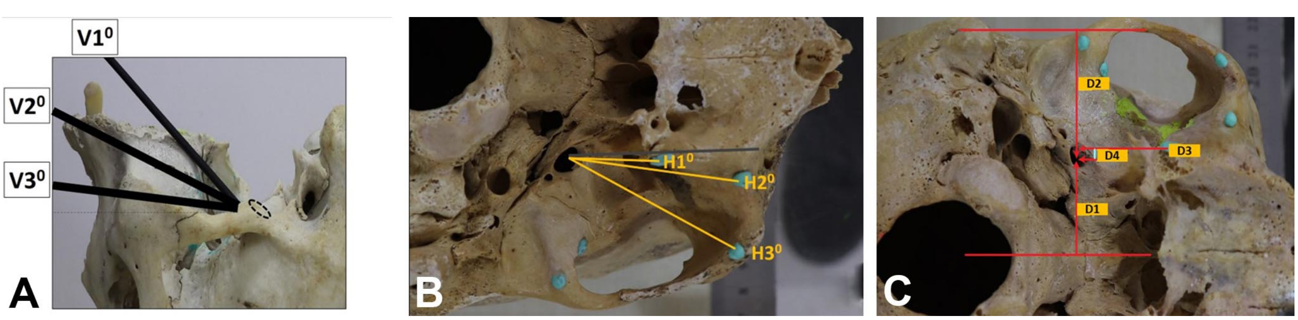

Fig. 2. A,B,C. Landmarks, vertical and horizantal angles, measured diameters.

the obtained data was done with the Shapiro-Wilk test. Right and left side differences were compared with the paired t-test. Correlation analysis was performed between the obtained values. The sexes of the skulls were uncertain. Therefore, a comparison between the sexes could not be made. Cohen-Kappa test statistics were used for interobserver variability in morphometric measurements. Statistical significance level was accepted as α=0.05.

RESULTS

The angle value was measured as 0 or negative value in 5 (20 %) of the H1 angle measurements made on the right side and 14 (56 %) on the left side. Interestingly, the H2 angle value was found to be smaller than the H1 angle in the skull 2 (8 %) on the right and 3 (12 %) on the left. Average values of horizontal angles (in degrees) on the right side; It was found 7.29 for H1, 12.15 for H2, 32.29 for H3. The mean values of vertical angular values (in degrees) were found as 44.07 for V1, 30.36 for V2, and 18.52 for V3. The mean value of the distance of the foramen ovale to the four landmarks (in mm) was found to be 31.40 for D1, 43.33 for D2, 32.08 for D3 and 6.08 for D4. Average values of horizontal angles (in degrees) on the left side; It was found 1.26 for H1, 9.46 for H2, and 30.56 for H3. The mean values of vertical angular values (in degrees) were found as 44.30 for V1, 29.42 for V2, and 16.67 for V3. The mean value of the distance of the foramen ovale to the four landmarks (in mm) was found to be 26.40 for D1, 39.72 for D2, 31.69 for D3 and 8.76 for D4 (Table I for detailed data). The difference between the horizontal angular values of the right and left sides is statistically significant p<0.005 (Table I). The difference between the vertical angular values of the right and left sides is not statistically significant. A significant difference was found between the right and left sides in 3 (D1, D2, D4) distance measurements related to the foramen ovale p<0.005 (Table I).

It was observed that there was a moderate positive correlation between the H1 angle and both the H2 angle and the D4 distance. Contrary to expectations, neither a positive nor a negative correlation was detected between the H1 angle and the distance of the foramen ovale to the zygion (D2). A medium-high level positive correlation was detected between the H2 angle and the H3 angle. No correlation could be detected between both H2 and H3 angles and D1, D2, D3 and D4 distances (Table II).

Vertical angles show a moderate positive correlation among themselves. In addition, a moderate positive correlation was found between V1 angle and D4 distance. A moderate positive correlation was detected between both V2 and V3 angles and D1 distance. There was no correlation between these angles and D2, D3, D4 distances (Table III).

Table I. Descriptive statistics and paired t test results.

Right	mean	*ss*	min, max,	Left	mean	*ss*	min, max,	*p*
V1	44.07	4.6	(29.65-51.17)		44.30	3.7	(37.98-54.06)	0.800
V2	30.36	4.8	(24.82-44.71)		29.42	6.3	(17.3-44.02)	0.571
V3	18.52	4.7	(11.85-29.59)		16.67	5.3	(8.31-25.65)	0.212
H1	7.29	6.5	(-4.60-22.90)		1.26	6.7	(-7.80-22.72)	0.000
H2	12.15	2.9	(5.05-16.25)		9.46	3.5	(2.45-18.69)	0.004
H3	32.29	2.5	(25.62-37.42)		30.56	3.3	(24.99-38.22)	0.026
D1	31.40	3.0	(24.22-37.91)		26.40	3.2	(20.18-31.67)	0.000
D2	43.33	3.5	(35.91-49.08)		39.72	3.4	(34.59-45.82)	0.000
D3	32.08	5.0	(24.25-43.78)		31.69	4.0	(22.83-40.28)	0.354
D4	6.08	3.4	(0-13.81)		8.76	3.0	(3.41-13.98)	0.005

P<0,005 significant difference between right and left sides*

Table II. Correlation analyses of the horizontal angles.

		H1	H2	H3	D1	D2	D3	D4
H1	r	1	.387*	0.136	0.260	0.266	0.175	.525**
	p	-	0.018	0.421	0.120	0.112	0.300	0.001
H2	r	.387*	1	.682**	0.245	0.308	0.275	0.196
	p	0.018	-	0.000	0.143	0.063	0.100	0.244
H3	r	0.136	.682**	1	0.286	0.224	0.217	0.012
	p	0.421	0.000	-	0.086	0.182	0.198	0.942

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table III. Correlation analyses of the vertical angles.

		V1	V2	V3	D1	D2	D3	D4
V1	r	1	.482**	.374*	0.092	0.158	-0.129	.325*
	p		0.002	0.019	0.576	0.336	0.433	0.044
V2	r	.482**	1	.438**	.327*	0.163	0.030	-0.065
	p	0.002		0.005	0.042	0.321	0.856	0.696
V3	r	.374*	.438**	1	.318*	0.122	0.230	-0.044
	p	0.019	0.005		0.049	0.458	0.159	0.790

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

For the treatment of trigeminal neuralgia, the fossa infratemporalis is passed by entering from the cheek and the foramen ovale is tried to be reached. This operation is usually successful. However, different holes or channels can be accidentally entered at the base of the skull. Examples of these are the external mouth of the carotid canal, foramen lacerum, and jugulare foramen (Inamasu & Guiot, 2005; Almeida *et al*., 2006; Kaplan *et al*., 2007). These structures always have a potential for miscannulation. Cannulation of the foramen ovale is an application that requires dexterity and practicality. Sometimes, this procedure cannot be performed initially, due to variations, such as soft tissue differences in patients and other reasons that may affect the dexterity of the physician. Proper and reliable training of the physician are needed for this procedure. Silicone models are recommended for assistants and young neurosurgeons (Zdilla *et al*., 2019). Cho *et al*. (2020) tried to reach the foramen ovale transorally with the anterior approach in cadavers and suggested that this method may be a useful method and an alternative to the Hartel technique.

In our study, three landmarks were determined to reach the foramen ovale with the anterior approach. In terms of angular values obtained from these landmarks, the results for H1 angular values were surprising. In our study, in some skulls, the H1 angle was towards the other side of the zero line, in other words, in the opposite direction. This opposite angulation was shown as negative angulation. Interestingly, this was not a rare situation in our study. In 19 of the 50 measurements we made, the H1 angle appeared as 0 or a negative value (Fig. 3). So what is the significance of this negative angle. This situation can be seen as a simple numerical data. However, a physician without proper knowledge of this data may advance the needle tip at an angle to the medial to reach the foramen ovale with the anterior approach, thus causing the process to fail. Furthermore, a physician who does not have this knowledge may enter the carotid canal or foramen lacerum while trying to reach the target by creating an angle to the medial, which may result in serious complications. For this reason, it is important to know that sometimes a negative lateral angulation may be required to reach the foramen ovale with a needle from the level of the upper third molar tooth. Acting according to the average values of the H1 angle will probably be the biggest reason for the failure of the procedure for the physician.

In 5 of our measurements, the H2 angle was found to be smaller than the H1 angle (Fig. 3). Two reasons for this situation have been identified. First; the juga alveolaria of the third molar tooth is excessively large and raised laterally. The second being; The palatal horizontal diameter is excessively wide compared to its sagittal length.

A different situation affecting the H1 angle is that the lamina lateralis of the pterygoid process of the sphenoid bone is excessively deviated to the lateral and obstructs the

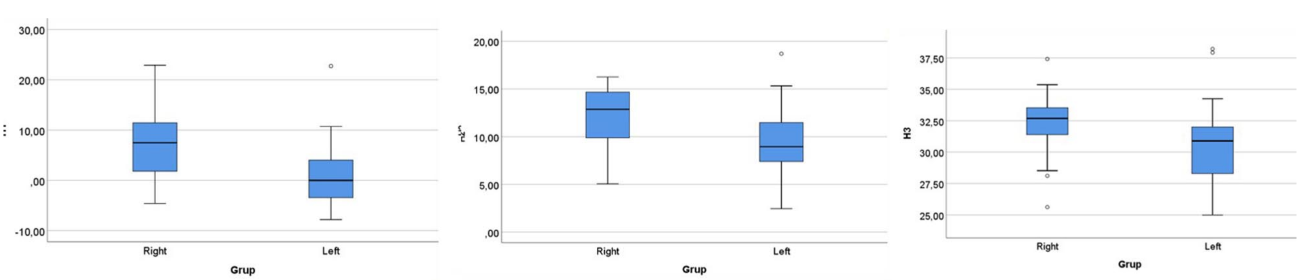

Fig. 3. Boxplot Graph of the horizontal angles distribution.

needle's path like a wall. For this reason, it was necessary to shift the route a little laterally to reach the foramen ovale, which caused the H1 angle to enlarge.

Interestingly, it is obvious that such situations, which complicate the task of establishing the right angle even during our study, will cause difficulties for the clinicians who will perform blind processes. For this reason, these 3 important factors in terms of hand practice must be added to the foresight pool by the physician who will perform the procedure.

For the V3 angular value, the foramen ovale was reached from the lateral lower margin of the crista zygomaticoalveolaris. Two important factors were affecting the angular results for this angular evaluation. One was that the crista zygomaticoalveolaris ridge differed not only between the skulls but also between the right and left sides. For this reason, the value of the angle of reaching the foramen ovale showed much variation due to the bony differences at the starting point. Interestingly, in some skulls, the foramen ovale and this lateral point were almost in the same plane, so a minimal angle (below 10 degrees) was sufficient to reach the foramen ovale (Fig. 4). The second important issue is that in some skulls, when the foramen ovale was reached from this lateral point, the internal part of the skull was reached by easily passing through the hole. However, an interesting situation is that the posterior wall of some foramen ovale was long and somewhat steep like a short canal, and therefore, even if you reached the foramen ovale, it did not allow entering at the same angle. In order to pass through the foramen ovale, you had to provide an angular change (increase) with a practical hand manipulation. Possibly this problem can be expected when passing through a canal-shaped anatomical structure. However, the word "foramen" in the naming of the foramen ovale may distract the physician, in that such an obstacle could be encountered. Even if the physician reaches the target foramen ovale, the posterior wall of the foramen will not allow the needle to pass through. For this reason, the physician needs to know that sometimes at this point an angular change must be made with a hand manipulation. Interestingly, in some skulls, the posterior wall was almost non-existent, and it was possible to pass through the foramen ovale easily even with a minimal horizontal angle.

Finally, in our study, there was a bone bridge in front of the foramen ovale in one skull and it affected some angular values. It also made it difficult to reach the foramen ovale (Fig .5).

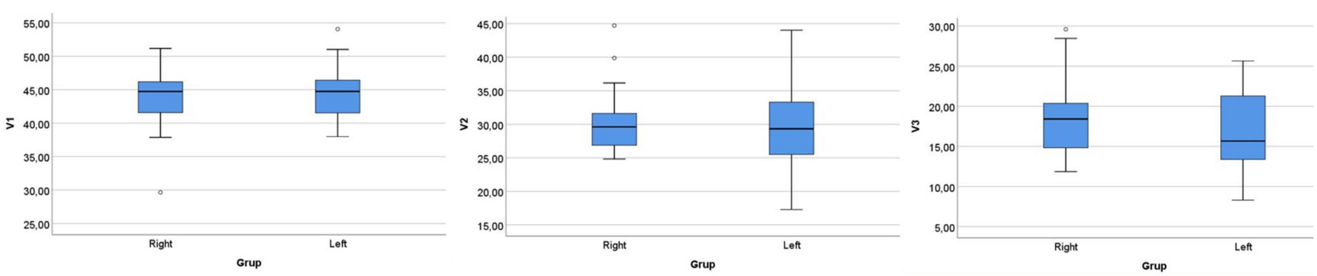

Fig. 4. Boxplot Graph of the vertical angles distribution.

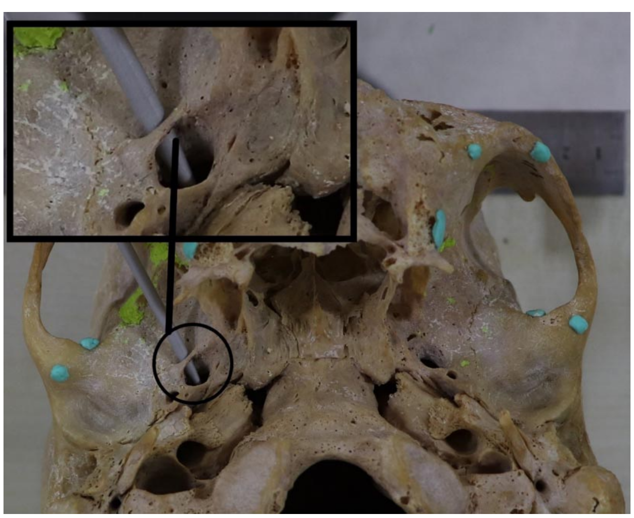

Fig. 5. Accessory bone bridge in front of the foramen ovale.

At the beginning of the discussion, I mentioned that there are articles suggesting that silicone models can be developed and used for assistants and young neurosurgeons to get used to the Hartel technique and improve their manual dexterity (Zdilla *et al*., 2019). We would also like to point out this. In our study, due to individual skull base and bone structure differences, the difficulties we experienced during the effort to reach the foramen ovale with the anterior approach and to establish standardization made us think that young neurosurgeons should spend more time on dry skulls to improve themselves in the post-graduate period.

CONCLUSION

This study has two important results. The first is that some angular values must be known to reach the foramen ovale with the anterior approach, and caution must be exercised during surgical procedures due to the negative horizontal angulation. Secondly, skull base differences and unpredictable, previously ignored differences in bone structure may pose challenges to neurosurgeons. For this reason, practical skills should be developed by examining the skull base structures in dry skulls in many different skulls.

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BAKIRCI, S. & YAYLA, R. S. Evaluación angular de posibles rutas que se pueden utilizar para alcanzar el agujero oval en el abordaje anterior. *Int. J. Morphol., 41(6)*:1706-1711, 2023.

RESUMEN: Para el tratamiento de la neuralgia del trigémino, se alcanza el foramen oval introduciendo una aguja en la mejilla. La termocoagulación se realiza con compresión con balón, administración de alcohol o radiofrecuencia. Aparte del método clásico, en teoría es posible alcanzar el foramen oval a través de la cavidad oral mediante el abordaje anterior. En nuestro estudio se tuvo como objetivo examinar horizontal y verticalmente los valores angulares que se deben dar a la aguja para alcanzar el foramen oval en el abordaje anterior. Se determinaron tres puntos de referencia en los lados derecho e izquierdo de 25 cráneos secos. Se insertó una varilla comenzando desde estos puntos de referencia y pasando por el centro del foramen oval. Se midieron los valores angulares verticales y horizontales de esta barra. Para cada foramen oval se realizaron mediciones de 3 ángulos verticales, 3 ángulos horizontales y 4 distancias. Hubo una diferencia significativa entre los lados derecho e izquierdo en términos de valores angulares horizontales. Valores medios de ángulos horizontales (en grados); a la derecha, 7,29 para H1, 12,15 para H2, 32,29 para H3; 1,26 para H1, 9,46 para H2 y 30,56 para H3 en el lado izquierdo ($p<0,005$). El valor del ángulo se midió como 0 o valor negativo en 5 (20 %) de las mediciones del ángulo H1 realizadas en el lado derecho y 14 (56 %) en el lado izquierdo. Se encontró que el valor del ángulo H2 era menor que el ángulo H1 en el cráneo 2 (8 %) a la derecha y 3 (12 %) a la izquierda. No hubo diferencia entre los lados derecho e izquierdo en términos de valores angulares verticales. Se encontró diferencia significativa entre el lado derecho e izquierdo en las distancias D1, D2, D4 ($p<0,005$). Se encontraron seis características anatómicas importantes que afectan los valores angulares.

PALABRAS CLAVE: Foramen oval; Rizotomía; Valores angulares; Abordaje anterior.

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Corresponding author:
Sinan Bakırcı, MD
Izmir Katip Celebi University
Faculty of Medicine
Department of Anatomy
Izmir
TURKEY

E-mail: sinan.bakirci@ikcu.edu.tr