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Golden Ratio for the Foramen Magnum On CT Images: A Morphological and Morphometrical Study

Proporción Áurea para el Foramen Magnum en Imágenes de TC: Un Estudio Morfológico y Morfométrico

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SUMMARY: The foramen magnum (FM) is a transition zone between the spine and skull. There is a study in the literature showing the golden ratio (4.62) and harmony between both FM and the anteroposterior and transverse diameters of the skull. The aim of this study is to examine the existence of this ratio on CT images and to investigate whether this ratio changes according to the FM shape types. In this study, 402 adult CT images belonging to the Turkish population were examined. Maximum cranial length (MCL), maximum cranial width (MCW) and the FM length (FML) and FM width (FMW) were measured. The different shapes of the FM were macroscopically classified. The number and incidence of each type in the studied skull was registered. In the 402 CT images used in the study, 12 FM shapes were detected. Three of the shape types observed in our study have not been reported in the literature until now, and were found in our study for the first time. In addition, our data supported that by using the ratio of 4.62, there was a great harmony between the skull and FM. The results obtained from the research show that there is a ratio of 4.62 between the basic cranial measurements and FM dimensions in all shapes except triangular shape. It is thought that repeating the calculated coefficients over more different FM shapes will contribute to the effectiveness of the proposed golden ratio.

KEY WORDS: Computed tomography; Craniometry; Foramen magnum; Golden ratio; Radiological anatomy.

INTRODUCTION

The foramen magnum (FM) is a three-dimensional aperture within the basal central region of the occipital bone and also is a transition zone between the spine and skull (Gruber *et al*., 2009; Akay *et al*., 2017). Its position between the brain and spinal cord plays an important role as an anatomic landmark. Therefore, the FM is a particularly interesting structure for anatomy, forensic medicine, and anthropology (Akay *et al*.). The knowledge of the detailed anatomy of the FM and variations is crucial for the safety of vital structures such as medulla, meninges, accessory spinal nerve, dural sinuses, as well as vertebral, posterior, and anterior spinal arteries. Many studies have focused on FM morphometric analysis, highlighting its clinical, orthopedic, neurosurgical, anthropological and forensic importance (Burdan *et al*., 2012; Kanodia *et al*., 2012; Natsis *et al*., 2013; Cirpan *et al*., 2016).

Anthropologists have suggested that the measurement-based morphometric method is as useful as the observational morphological method (Günay & Altinkök, 2000). First, Teixeira (1982) reported that FM-related measurements can help predict sex, and since then several studies have been published on evaluating FM dimensions for sex prediction in different populations (Günay & Altinkök; Manoel *et al*., 2009; Mahakkanukrauh *et al*., 2015; Ramamoorthy *et al*., 2016; Madadin *et al*., 2017). In addition, the knowledge of the dimensions and shape of the FM has important clinical implications in the prognosis and treatment

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of various neurological pathologies like Arnold Chiari syndrome, and posterior cranial fossa lesions (Ulutabanca *et al*., 2015; Singh *et al*., 2019).

The golden ratio can be found throughout nature and the physical world. It manifests in biological structural proportions as diverse as the structure of DNA, the proportions of the mandible, and the configuration of facial features (Pietak *et al*., 2013). In this context, Ulcay *et al*. (2021) reported a proportional relationship between maximum cranial length (MCL) and maximum cranial width (MCW) measurements and FM length (FML) and FM width (FMW) measurements in their study on 60 adult dry skulls with 8 different FM shapes. In their related study, which they evaluated as a pilot study, the researchers reported that the rate of 4.62 they found in more skulls and different FM forms should be tested. The aim of this study is to examine the existence of this ratio on CT images and to investigate whether this ratio changes according to the FM shape types.

MATERIAL AND METHOD

Participants. In this study, the measurements obtained from CT images of 402 randomly selected patients who applied to Kırsehir Ahi Evran University Training and Research Hospital with headache complaints and did not have any pathology were used as retrospective data. This study was approved by the Kırsehir Ahi Evran University Ethical Board (2021-05/47). FMW and FML were estimated using Equation 1 and Equation 2 given by Ulcay *et al*.

$$FM\ Width = \frac{cranial\ width}{4.62} \quad (1)$$

$$FM\ Length = \frac{cranial\ Length}{4.62} \quad (2)$$

Morphometric Measurements and Morphology. The FML was measured from the end of the anterior margin (basion) to the end of the posterior margin (opisthion) of FM. The FMW was measured from the point of maximum concave on the right edge to the maximum concave on the left edge of FM (Fig. 1A). The MCL was assumed as the distance between the glabella (g) and opisthocranion (g-op) in sagittal plane image (Fig. 1B). The MCW was measured between the two most remote points (eurion-eurion) located on the right and the left side of the skull (eu-eu) in coronal plane image (Fig. 1C).

In the study, descriptive statistics were calculated for all 402 CT images and for each individual FM shape. FML (Observed) and FMW (Observed) measured from CT images were compared with FML (Prediction) and FMW (Prediction) calculated with the help of Equation 1 and Equation 2. When the observed value and the predicted value are close to each other, the difference between them is expected to be equal to zero. The difference between prediction values and observed values gives us information about the estimation error rate. From this point of view, the differences between observed values and prediction values for both FML and FMW were examined in order to determine whether the estimated FML and FMW were close to the real values. The ratio of an observation value to its predicted value should be close to 1. If the predicted value is equal to the observed value, the ratio observed values / prediction values will be equal to 1. In order to determine the accuracy of the predicted values obtained in the study, the observed values obtained for FML and FMW were proportioned to the predict values.

The different shapes of the FM were macroscopically noted and classified as two semicircle, oval, round, triangular, egg, tetragonal, pentagonal, hexagonal, heptagonal, octangular, drop, and irregular shapes. The shapes were

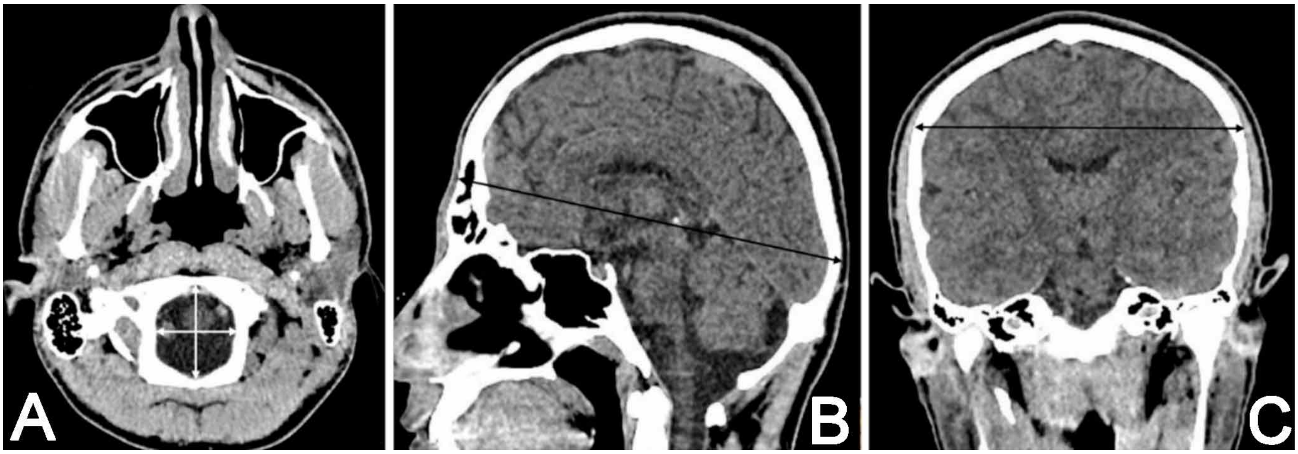

Fig. 1. Length measurements MR images in three plane. a: Foramen magnum length (FML) and Foramen magnum width (FMW), b: Maximum cranial length (MCL), c: Maximum cranial width (MCW).

determined after the discussion with team of three members in order to avoid observational bias. The number and incidence of each type in the studied skull was registered and tabulated.

Statistical Analysis. In the study, the normality assumptions of the data were tested with Kolomogorov-Smirnov and Shapiro-Wilk tests. Independent t test was used for group comparisons. Descriptive statistics of variables providing normality assumption are given as mean ±standard deviation, and descriptive statistics of variables that do not provide normality assumption are given as median (Min-Max). Statistical analysis of the study was performed using Statistical Package for Social Sciences version 25.0 software for Windows (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp., USA).

RESULTS

In our study, 213 (53.0 %) male and 189 (47.0 %) female patients were included. The average age of the participants is 45.64±17.44 years. In the 402 CT images used in the study, 12 FM shapes were detected, and the frequencies of the shapes are given in Table I. In terms of FM shape, it is the two semicircle (23.9 %) with the highest frequency.

Statistics of the differences between observed and predicted FM values are summarized in Table II. According to Table II, the difference between the average of observed FML values of 402 patients (36.25±2.14) and the average of predicted FML values (36.56±2.09) was statistically insignificant (P> 0.05). In this study, no statistical comparison could be made for the octangular FM shape, which was detected for the first time and was not included in the literature before. When the other 11 FM shapes detected in the study were evaluated separately, the difference between observed FML values and predicted FML values in all FM shapes except the triangular FM shape was statistically insignificant (P>0.05). The difference between the mean observed FML (34.52±2.03) and the mean predicted FML (38.21±0.42) in the shape of triangular FM was statistically significant (P<0.01). When Table II was examined, in terms of FMW, the difference between observed values and predicted values in all FM shapes in the study was found to be statistically insignificant (P> 0.05).

Table I. Frequency of different shape types of FM (n = 402).

	FM Shape Type	n(%)
1	Drop Shaped	24(6.0)
2	Egg Shaped	20(5.0)
3	Heptagonal	3(0.7)
4	Hexagonal	67(16.7)
5	Irregular	54(13.3)
6	Octangular	1(0.2)
7	Oval	38(9.5)
8	Pentagonal	20(5.0)
9	Round	38(9.5)
10	Tetragonal	36(9.0)
11	Triangular	5(1.2)
12	Two Semicircle	96(23.9)
	Total	402(100.0)

When the difference between observed FML and predicted FML values was examined as a measure of the accuracy of the predicted values, the median values of the differences were zero in the irregular [0.00(-0.15 - 3.08)], pentagonal [(0.00(-0.39 - 2.48)] and round [0.00(-0.02 - 2.64)] shapes. Only in the form of triangular FM, the difference between observed and predicted values in terms of FML is very different from zero. When the differences between the observed and predicted values in terms of FMW were examined, the median values of the differences in the pentagonal [0.00(-3.56 - 1.86)], round [0.00(-2.52 - 2.42)] and two semicircle [0.00(-3.93 - 3.33)] shapes were zero. The median values of the differences between the observed FMW and the predicted FMW were close to zero in all FM shapes except the triangular [-3.19(-4.37 - 0.72)] FM shape. The median value of the difference between the observed FMW and the predicted FMW of all 402 CT images was also close to zero [-0.13(-4.37 - 4.81)]. When the observed FML / predicted FML and observed FMW / predicted FMW ratios are examined in Table II, this ratio was found close to 1 (one) or 1 (one) in all FM shapes except the triangular FM shape. The observed FML / predicted FML [1.02±0.03] and observed FMW/ predicted FMW [0.99±0.06] of all 402 CT images examined in the study were also very close to 1 (One).

Calculated MCW / FMW and MCL / FML ratios of 11 FM shapes determined in the study are summarized in Table III. In the form of triangular FM, the MCW / FMW ratio (4.33±0.33) was found outside the confidence interval of the golden ratio [4.62±0.35 (95 % CI: 4.52 - 4.70)] value given in Ulcay *et al*. The MCL / FML (5.13±0.30) value of the triangular FM shape is also outside the confidence interval of the golden ratio [4.62±0.50 (95 % CI: 4.49 - 4.76)] value given in Ulcay *et al*. The MCW / FMW and MCL / FML ratios of all other FM shapes except the triangular FM shape are within the golden ratio confidence intervals given in Ulcay *et al*. Although varying according to the FM shapes, MCW / FMW and MCL / FML ratios were found close to 4.62. The MCW / FMW ratio (4.58±0.28) and the MCL / FML ratio (4.72±0.15) of all 402 CT images were found close to the golden ratio (4.62) given in Ulcay *et al*. and within the confidence intervals calculated for the coefficient.

Table II. Comparison of observed and predicted values according to the shape types.

	Shape Type	n	FML Observed Mean±SD	FML Predicted Mean±SD	*P*	FM Width (FMW) Observed Mean±SD	FM Width (FMW) Predicted Mean±SD	*P*	FML Observed-Predicted Median(Min-Max)	FMW Observed-Predicted Median(Min-Max)	ObsFML/PredFML	ObsFMW/PredFMW
1	Drop Shaped	24	35.9±1.27	36.5±1.02	.070	29.27±1.66	28.61±1.13	.115	0.70(0.99 - 1.65)	0.66(1.52 - 3.07)	1.01±0.02	0.97±0.03
2	Egg Shaped	20	34.25±1.99	34.86±2.62	.408	28.28±1.46	28.44±1.21	.697	0.24(-1.48 - 2.75)	0.10(-3.80-4.20)	1.01±0.03	1.00±0.07
3	Heptagonal	3	34.10±2.17	36.34±0.89	.175	28.33±1.70	28.40±1.35	.960	1.87(1.13- 3.72)	0.83(-2.39-1.76)	1.06±0.04	1.0±0.07
4	Hexagonal	67	36.82±1.78	37.38±1.53	.067	29.15±1.79	28.52±1.31	.069	0.08(-0.08 - 2.80)	-0.97(-3.73 - 1.43)	1.01±0.02	0.95±0.04
5	Irregular	54	35.62±2.07	36.67±1.43	.089	28.32±2.06	28.57±1.33	.280	0.00(-0.15 - 3.08)	0.14(-3.18 - 4.15)	1.03±0.03	1.01±0.06
6	Oval	38	36.43±2.10	37.28±1.83	.124	28.43±1.74	28.36±1.49	.847	1.11(-0.89 - 3.34)	-0.25(-3.82 - 4.81)	1.02±0.03	0.99±0.05
7	Pentagonal	20	36.51±1.50	36.98±1.20	.278	29.03±2.09	28.83±1.44	.733	0.00(-0.39 - 2.48)	0.00(-3.56 - 1.86)	1.01±0.02	0.99±0.03
8	Round	38	36.78±2.02	37.31±1.84	.234	29.27±1.67	29.04±1.37	.513	0.00(-0.02 - 2.64)	0.00(-2.52 - 2.42)	1.01±0.02	0.99±0.03
9	Tetragonal	36	35.63±2.17	36.04±2.08	.422	28.81±1.95	28.87±1.41	.900	0.05(-1.28 - 2.74)	0.37(-3.84 - 3.95)	1.01±0.02	1.00±0.07
10	Triangular	5	34.52±2.03	38.21±0.42	.004	30.14±2.87	28.14±1.84	.226	4.39(1.65 - 6.39	-3.19(-4.37 - 0.72)	1.11±0.06	0.93±0.07
11	Two Semicircle	96	36.02±2.03	36.56±1.97	.061	28.96±2.08	28.83±1.33	.602	0.08(-0.48-3.46)	0.00(-3.93 - 3.33)	1.00±0.03	0.99±0.06
	Total	401	36.25±2.14	36.56±2.09	.055	28.98±1.95	28.81±1.61	.181	0.08(-1.48 - 6.39)	-0.13(-4.37 - 4.81)	1.02±0.03	0.99±0.06

FML: Foramen Magnum Length, FMW: Foramen Magnum Width, Obs: Observed, Pred: Predicted. Octangular shape is not included in the table by reason of statistical analysis cannot be made.

Table III. MCW / FMW and MCL / FML ratios for all FM shapes.

	FM Shape Types	n	MCW/FMW Mean_SD	MCL/FML Mean_SD
1	Drop Shaped	24	4.52±0.15	4.70±0.09
2	Egg Shaped	20	4.65±0.32	4.70±0.15
3	Heptagonal	3	4.64±0.34	4.93±0.20
4	Hexagonal	67	4.42±0.20	4.69±0.11
5	Irregular	54	4.67±031	4.76±0.17
6	Oval	38	4.61±0.27	4.77±0.14
7	Pentagonal	20	4.59±0.18	4.68±0.12
8	Round	38	4.58±0.16	4.68±0.12
9	Tetragonal	36	4.64±0.36	4.67±0.12
10	Triangular	5	4.33±0.33	5.13±0.30
11	Two semicircle	96	4.62±0.30	4.63±0.15
12	Total	401	4.58±0.28	4.72±0.15

FML: Foramen Magnum Length, FMW: Foramen Magnum Width, MCL: Maximum cranial length, MCW: Maximum cranial width. Octangular shape is not included in the table by reason of statistical analysis cannot be made.

Twelve different shapes were observed for the FM. Type, quantity, and frequency of these are shown in Figure 2 and Table II. Three of the shape types (drop shaped, triangular and octangular) observed in our study have not been reported in the literature until now, and were found in our study for the first time (Fig. 2).

DISCUSSION

The cranial base is so complex that it is essential to examine the diameters of FM from a descriptive and topographical point of view because of the important relationship of FM with its content. Besides, the dimensions of FM are clinically superior because the vital structures that pass through it can be subjected to compression. This may be the cause of some pathologies arising from mechanical and spatial problems (Catalina-Herrera, 1987). From a radiographic point of view, knowledge of FM's diameters is of particular importance for determining some malformations such as Arnold-Chiari syndrome. Kruyff & Jeffs (1966), considered that enlargements of the anteroposterior and transverse diameter of FM are typical of this malformation. Therefore, the anteroposterior and transverse diameter of FM is important for the pathologies of this region.

Ulcay *et al*. reported a proportional relationship of 4.62 between MCL and FML and between MCW and FMW. The present study is about checking the validity of this assumed golden ratio by increasing the number of subjects and how this ratio changes according to FM shape types.

For comparison, both maximum cranial and FM diameters should be measured in any given study. In this context, there are very few studies in the literature. For example, in the study

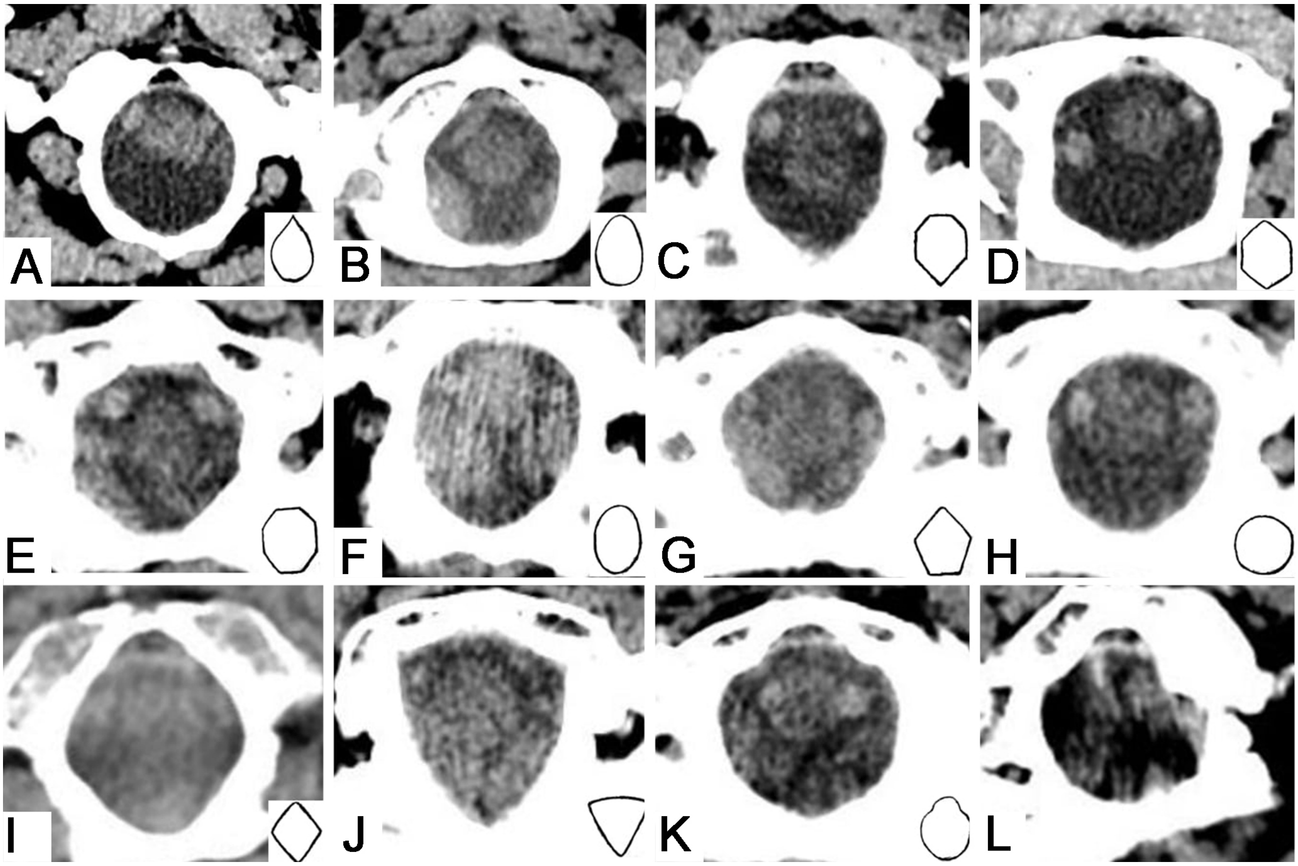

Fig. 2. Different shape types of the FM on CT views; A. Drop-shaped; B. Egg-shaped; C. Heptagonal; D. Hexagonal; E. Octangular; F. Oval; G. Pentagonal; H. Round; I. Tetragonal; J. Triangular; K. The hole formed by the combination of two semicircles; L. Irregular.

conducted by Rooppakhun *et al*. (2010) on 91 Thai CT images, the MCL / FML ratio is 4.70 in male and 4.81 in female, while the MCW / FMW ratio is 4.69 in male and 4.87 in female. While these ratios are very close to the golden ratio reported by Ulcay *et al*. for males, it is seen that they are slightly away from this ratio in females. According to the results of Burdan *et al*., it is seen that the MCW / FMW ratios (Male: 4.53, Female: 4.65) in both male and female are within the confidence interval reported by Ulcay *et al*. Length ratios (MCL / FMW) in both sexes were found to be very close to the confidence interval (Male: 4.89, Female: 4.86). When the results obtained by Mahakkanukrauh *et al*. from 200 dried skulls were adapted to the equations reported by Ulcay *et al*., the ratios obtained in both genders were found to be very close to the golden ratio and confidence interval reported as 4.62 (MCL/FML: 4.83 in male, 4.90 in female – MCW/FMW: 4.72 in male, 4.80 in female). Ulcay *et al*. stated that the ratios obtained from the width values reported in the study conducted by Ramamoorthy *et al*. on 70 Indian adult skulls were lower for both sexes compared to the literature (MCW/FMW: 4.25 in male, 4.17 in female), the ratio of maximum cranial length to FM length (MCL/FML) was found within the confidence interval in females and very close confidence interval in males (male: 4.87, female: 4.67).

The current study stands out as the study analyzing the largest number of subjects in the literature with 402 subjects in terms of examining FM morphometry. Therefore, the large number of subjects in our study enabled us to examine the golden ratio reported by Ulcay *et al*. according to FM shape types. In our study, the results obtained in the analysis performed on a total of 402 FM regardless of the FM shapes showed that both FM width and FM length can be calculated using the 4.62 golden ratio from basic cranial measurements (MCL and MCW) (Table III). In the present study, while the MCL / FML ratio was 4.72±0.15, the MCW / FMW ratio was found to be 4.58±0.28. Both length and width ratios were found within the golden ratio confidence interval reported by Ulcay *et al*. [4.62±0.50 (95 % CI: 4.49 - 4.76)]. Thus, regardless of the FM shape types, the data of our study fully supports Ulcay *et al*. prediction. In the evaluation according to FM shape types, it is seen that as the number examined increases, the MCL / FML and MCW / FML ratios approach to 4.62 (Table III). In this context, the length and width ratios of FM shape types also support the golden ratio reported by Ulcay *et al*.

Also in the study of Ulcay *et al*., they found the observed FML / predicted FML and observed FMW / predicted FML ratios very close to 1 (1.01). In other words, they reported that observed values and predicted values are approximately equal to each other. According to the literature, this equality is supported by many studies (Rooppakhun *et al*.; Burdan *et al*.; Mahakkanukrauh *et al*.). In Ramamoorthy *et al*. study, this equation was slightly lower in both genders (0.87 for male, 0.89 for female). This may be due to the small number of subjects. In our study, the observed FML / predicted FML and observed FMW / predicted FMW ratios were found to be approximately equal to 1 (One) (Table II).

The shape of FM is variable and continues to be controversial in previous studies in different populations (Akay *et al*.,). Standard textbooks describe the foramen magnum as an oval shape (Schaeffer, 1953). However, studies have shown that FM is not completely oval in shape (Govsa *et al*., 2011; Chethan *et al*., 2012; Aragão *et al*., 2014; Sharma *et al*., 2015; Ramamoorthy *et al*.; Akay *et al*.; Moodley *et al*., 2019; Ulcay *et al*.). The most frequently observed FM type was reported as oval shaped by Singh *et al*. (33.3 %), as round shaped by Chethan *et al*. (22.6 %) and Sharma *et al*. (22 %), as tetragonal shaped by Govsa *et al*. (25.66 %), as pear shaped by Aragão *et al*. (25.66 %) and as egg shaped by Moodley *et al*. (20.67 %). In the present study, two semicircle shape was most common shape of the FM (23.9 %). In addition, this study stands out with the definition of 3 new forms of FM shape type (drop shaped, triangular and octangular shapes) that have not been reported in the literature until now (Figs. 2 a, e, j) (Table IV).

The results showed that there is a ratio of 4.62 between MCL and FML, and between MCW and FMW. As a result of the calculations made over a total of 402 CT scans, it was determined that the measurements and ratios of the triangular FM shape were out of the ratio of 4.62 compared to other FM shapes. It was determined that as the number of examined FM shapes increased, as in the form of two semicircle, the MCL / FML and MCW / FMW ratios were closer to 4.62.

The fact that there is no significant difference between the observed and prediction FM values, the differences between the observed and prediction values of both FML and FMW values are very close to zero, and the observed/prediction ratios are very close to one show the validity of the golden ratio given by Ulcay *et al*. It shows that, by using this ratio, FML and FMW values can be accurately estimated with MCL and MCW measurements.

Considering that the study was conducted on CT images, it is thought that repeating the calculated coefficients over more adult human dry skulls and different FM shapes will contribute to the effectiveness of the proposed golden ratio.

Table IV. Comparison of different shape types of FM with the previous reports.

Different shapes of FM	Akay *et al.*	Singh *et al.*	Chethan *et al.*	Govsa *et al.*	Sharma *et al.*	Aragão *et al.*	Moodley *et al.*	Ulcay *et al.*	Current Study
	N (%)	N (%)	N (%)	N (%)	N (%)	**N (%)**	N (%)	N (%)	N (%)
Oval	24 (12.6)	40 (33.3)	8 (15.1)	30 (7.93)	8 (16)	6 (5.5)	2 (1.33)	12 (20)	38 (9.5)
Two semicircle	-	-	-	88 (23.28)	-	-	-	10 (16.67)	96 (23.9)
Tetragonal	15 (7.9)	20 (16.6)	10 (18.9)	97 (25.66)	6 (12)	12 (10.9)	18 (12)	6 (10)	36 (9)
Pentagonal	18 (9.5)	16 (13.3)	2 (3.8)	16 (4.23)	4 (8)	3 (2.7)	20 (13.33)	5 (8.33)	20 (5)
Hexagonal	35 (18.4)	20 (16.6)	3 (5.61)	63 (16.67)	4 (8)	10 (9.1)	24 (16)	5 (8.33)	67 (16.7)
Round	41 (21.6)	16 (13.3)	12 (22.6)	15 (3.97)	11 (22)	17 (15.5)	14 (9.3)	4 (6.67)	38 (9.5)
Pear	-	8 (6.6)	-	-	-	41 (37.3)	-	-	-
Biconvex	-	-	-	-	-	12 (10.9)	-	-	-
Irregular	44 (23.2)	-	8 (15.1)	17 (4.50)	9 (18)	7 (6.4)	13 (8.67)	10 (16.67)	54 (13.4)
Egg Shaped	13 (6.8)	-	10 (18.9)	52 (13.75)	8 (16)	-	31 (20.67)	8 (13.33)	20 (5)
Drop Shaped	-	-	-	-	-	-	-	-	24 (6)
Heptagonal	-	-	-	-	-	2 (1.8)	28 (18.67)	-	3 (0.7)
Octangular	-	-	-	-	-	-	-	-	1 (0.2)
Triangular	-	-	-	-	-	-	-	-	5 (1.2)
Total	190 (100)	120 (100)	53 (100)	352 (100)	50 (100)	110 (100)	150 (100)	60 (100)	402 (100)

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RESUMEN: El foramen magno (FM) es una zona de transición entre la columna y el cráneo. Existe un estudio en la literatura que muestra la proporción áurea (4,62) y la armonía entre el FM y los diámetros anteroposterior y transversal del cráneo. El objetivo de este estudio fue examinar la existencia de esta relación en las imágenes de TC e investigar si esta relación cambia según los tipos de forma del FM. Se examinaron 402 imágenes de TC de adultos pertenecientes a la población turca. Se midieron la longitud craneal máxima, el ancho craneal máximo y la longitud del FM y la anchura del FM. Las diferentes formas del FM se clasificaron macroscópicamente. Se registró el número e incidencia de cada tipo en el cráneo estudiado. En las 402 imágenes de TC utilizadas en el estudio, se detectaron 12 formas de FM. Tres de los tipos de formas observados en nuestro estudio no se han reportado en la literatura consultada describiéndose por primera vez. Además, nuestros datos respaldaron que al usar la proporción de 4,62, había una armonía importante entre el cráneo y el FM. Los resultados obtenidos de la investigación muestran que existe una relación de 4,62 entre las medidas craneales básicas y las dimensiones de la FM en todas las formas excepto en la triangular. Se cree que la repetición de los coeficientes calculados en más formas de FM diferentes contribuirá a la eficacia de la proporción áurea propuesta.

PALABRAS CLAVE: Tomografía computarizada; Craneometría; Foramen magnum; Proporción áurea; Anatomía radiológica.

REFERENCES

Akay, G.; Güngör, K. & Peker, I˙. Morphometric analysis of the foramen magnum using cone beam computed tomography. *Turk. J. Med. Sci., 47(6)*:1715-22, 2017.

Aragão, J. A.; de Oliveira Pereira, R.; de Moraes, R. Z. & Reis, F. P. Morphological types of foramen magnum. *Ann. Res. Rev. Biol., 4*:1372-8, 2014.

Burdan, F.; Szumio, J.; Walocha, J.; Klepacz, L.; Madej, B.; Dworzanski, W.; Klepacz, R.; Dworzanska, A.; Czekajska-Chehab, E. & Drop, A. Morphology of the foramen magnum in young Eastern European adults. *Folia Morphol. (Warsz.), 71(4)*:205-16, 2012.

Catalina-Herrera, C. J. Study of the anatomic metric values of the foramen magnum and its relation to sex. *Acta Anat. (Basel), 130(4)*:344-7, 1987.

Chethan, P.; Prakash, K. G.; Murlimanju, B. V.; Prashanth, K. U.; Prabhu, L. V.; Saralaya, V. V.; Krishnamurthy, A.; Somesh, M. S. & Kumar, C. G. Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. *Turk. Neurosurg., 22 (4)*:416-9, 2012.

Cirpan, S.; Yonguc, G. N.; Mas, N. G.; Aksu, F. & Magden, A. O. Morphological and Morphometric Analysis of Foramen Magnum: An Anatomical Aspect. *J. Craniofac. Surg., 27(6)*:1576-8, 2016.

Govsa, F.; Ozer, M. A.; Celik, S. & Ozmutaf, N. M. Three-dimensional anatomic landmarks of the foramen magnum for the craniovertebral junction. *J. Craniofac. Surg., 22(3)*:1073-6, 2011.

Gruber, P.; Henneberg, M.; Böni, T. & Rühli, F. J. Variability of human foramen magnum size. *Anat. Rec. (Hoboken), 292(11)*:1713-9, 2009.

Günay, Y. & Altinkök, M. The value of the size of foramen magnum in sex determination. *J. Clin. Forensic Med., 7(3)*:147-9, 2000.

Kanodia, G.; Parihar, V.; Yadav, Y. R.; Bhatele, P. R. & Sharma, D. Morphometric analysis of posterior fossa and foramen magnum. *J. Neurosci. Rural Pract., 3 (3)*:261-6, 2012.

Kruyff, E. & Jeffs, R. Skull abnormalities associated with the Arnold Chiari malformation. *Acta Radiol. Diagn. (Stockh.)*, 5:9-24, 1966.

Madadin, M.; Menezes, R. G.; Al Saif, H. S.; Abu Alola, H.; Al Muhanna, A.; Gullenpet, A. H.; Nagesh, K. R.; Kharoshah, M. A. & Al Dhafery, B. Morphometric evaluation of the foramen magnum for sex determination: A study from Saudi Arabia. *J. Forensic Leg. Med., 46*:66-71, 2017.

Mahakkanukrauh, P.; Sinthubua, A.; Prasitwattanaseree, S.; Ruengdit, S.; Singsuwan, P.; Praneatpolgrang, S. & Duangto, P. Craniometric study for sex determination in a Thai population. *Anat. Cell Biol., 48(4)*:275-83, 2015.

Manoel, C.; Prado, F. B.; Caria, P. H. F. & Groppo, F. C. Morphometric analysis of the foramen magnum in human skulls of Brazilian individuals: its relation to gender. *Braz. J. Morphol. Sci., 26 (2)*:104-8, 2009.

Moodley, M.; Rennie, C.; Lazarus, L. & Satyapal, K. S. The morphometry and morphology of the foramen magnum in age and sex determination within the South African Black Population utilizing computer tomography (CT) scans. *Int. J. Morphol., 37(1)*:251-7, 2019.

Natsis, K.; Piagkou, M.; Skotsimara, G.; Piagkos, G. & Skandalakis, P. A morphometric anatomical and comparative study of the foramen magnum region in a Greek population. *Surg. Radiol. Anat., 35(10)*:925-34, 2013.

Pietak, A.; Ma, S.; Beck, C. W. & Stringer, M. D. Fundamental ratios and logarithmic periodicity in human limb bones. *J. Anat., 222(5)*:526-37, 2013.

Ramamoorthy, B.; Pai, M. M.; Prabhu, L. V.; Muralimanju, B. V. & Rai, R. Assessment of craniometric traits in South Indian dry skulls for sex determination. *J. Forensic Leg. Med., 37*:8-14, 2016.

Rooppakhun, S.; Surasith, P.; Vatanapatimakul, N.; Kaewprom, Y. & Sitthiseripratip, K. Craniometric study of Thai skull based on three-dimensional computed tomography (CT) data. *J. Med. Assoc. Thai., 93(1)*:90-8, 2010.

Schaeffer, J. P. *Morris' Human Anatomy.* New York, The Blakiston Division, McGraw-Hill Book Company, 1953.

Sharma, S.; Sharma, A. K.; Modi, B. S. & Arshad, M. Morphometric evaluation of the foramen magnum and variation in its shape and size: a study on human dried skull. *Int. J. Anat. Res., 3(3)*:1399-403, 2015.

Singh, A.; Agarwal, P. & Singh, A. Morphological and morphometric study of foramen magnum in dry human skull and its clinical significance. *Int. J. Anat. Radiol. Surg., 8(3)*:AO10-2, 2019.

Teixeira, W. R. Sex identification utilizing the size of the foramen magnum. *Am. J. Forensic Med. Pathol., 3(3)*:203-6, 1982.

Ulcay, T.; Kamas¸ak, B.; Görgülü, Ö.; Uzun, A. & Aycan, K. A golden ratio for foramen magnum: an anatomical pilot study. *Folia Morphol. (Warsz.)*, 2021. DOI: https://www.doi.org/10.5603/FM.a2021.0018

Ulutabanca, H.; Acer, N.; Küçük, A.; Dogan, S.; Tümtürk, A.; Kurtsoy, A.; Sagıroglu, A. & Bilgen, M. *Chiari type I malformation with high foramen magnum anomaly. Folia Morphol. (Warsz.), 74(3)*:402-6, 2015.

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