

Evaluation of the Golden Ratio in Atlas with its Unique Anatomical Features

Evaluación de la Proporción Áurea en el Atlas y sus Características Anatómicas Únicas

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SUMMARY: This study aimed to evaluate whether selected morphometric ratios of the atlas conform to the golden ratio by analyzing anatomical landmarks and parameters specific to its unique morphology. Cone beam computed tomography images of 359 individuals (180 males, 179 females), aged 18–82 years, were analyzed to assess the morphometric parameters of the atlas. 22 morphometric parameters of the atlas were measured, and 57 ratios were calculated from these measurements. Based on the mean value of each assessed ratio and the corresponding standard deviation (SD), the cases were classified into four groups. Descriptive statistics of the measurements and calculated ratios were determined, including mean, SD, median, 25th and 75th percentiles, count, and percentage frequencies. The deviation of the calculated ratios from the golden ratio was examined using a One-Sample t-test. Among the 57 calculated ratios, the golden ratio was observed only in P9/P22 ($p = 0.410$) and P18/P14 ($p = 0.159$). Several other ratios had mean values close to 1.618, including P1/P2 (1.697 ± 0.103), P1/P15 (1.664 ± 0.120), P9/P21 (1.685 ± 0.320), P10/P22 (1.691 ± 0.418), P12/P22 (1.691 ± 0.418), P18/P13 (1.661 ± 0.284), and P18/P20 (1.695 ± 0.401); however, these ratios differed significantly from the golden ratio. The findings provide valuable insights into the relationship between atlas morphometric ratios and the golden ratio in this Turkish population sample. Several ratios were found to be numerically close to the golden ratio. These results provide reference data on atlas morphometry and suggest that selected proportional relationships of the atlas may reflect its distinctive anatomical organization.

KEY WORDS: Atlas morphometry, Fibonacci series, Golden ratio, Symmetry, Turkish population

INTRODUCTION

The cervical region of the vertebral column comprises seven vertebra, sequentially numbered from C1 to C7. While they generally share similar morphological characteristics, certain vertebra in the cervical region exhibit distinctive structural differences, classifying them as atypical vertebra (Kolenkiewicz *et al.*, 2018). The first cervical vertebra, the atlas, is one of these atypical vertebra and is characterized by the absence of a vertebral body and spinous process (Sertel Meyvaci *et al.*, 2020). A literature review indicates that, in addition to its anatomical significance, the atlas also exhibits sexually dimorphic characteristics (Sanabria Medina *et al.*, 2011; Padovan *et al.*, 2019). The golden ratio (ϕ or F) represents a value that is aesthetically pleasing to the human eye (Walker *et al.*, 2011). With an approximate value of 1.618, the golden ratio was first described in antiquity by Pythagoras and later developed by Leonardo Pisano Fibonacci in 1202

(Henein *et al.*, 2011; Benavoli *et al.*, 2009). The golden ratio is obtained by dividing a line into two segments: when the longer segment (a) is divided by the shorter segment (b), and the sum of both segments ($a + b$) is divided by the longer segment (a), the result is 1:1.618 (Walker *et al.*, 2011). Both the golden ratio and the associated golden angle of 137.5° have been identified in certain proportions and angles within the human body and nature (Henein *et al.*, 2011). Studies have demonstrated that the golden ratio appears not only in the human genome (Yamagishi *et al.*, 2008) and cellular structure (Purnell *et al.*, 2018) but also in various physical characteristics, such as gait mechanics (Iosa *et al.*, 2013; Iosa *et al.*, 2016) and the aesthetic dimensions of the face (Bashour, 2006; Kim, 2007; Lipiec *et al.*, 2019). Furthermore, it has been utilized in aesthetic surgical procedures on different body regions to determine the ideal proportions (Raposio *et al.*, 2024).

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Although the golden ratio has been evaluated in different anatomical regions, its possible relationship with the morphometric parameters of the atlas has not been sufficiently investigated. Therefore, the present study aimed to evaluate whether selected morphometric ratios of the atlas conform to the golden ratio by analyzing anatomical landmarks and parameters specific to its unique morphology.

MATERIAL AND METHOD

This study retrospectively analyzed cone-beam computed tomography (CBCT) images of 359 individuals, including 180 males and 179 females, aged 18–82 years, who presented to the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Bolu Abant Izzet Baysal University, between 2020 and 2024. The images were evaluated to assess the morphometric parameters of the atlas. Ethical approval for the study was obtained from the Bolu Abant Izzet Baysal University Non-Interventional Clinical Research Ethics Committee with decision number 2024/382. The ratios between the parameters were calculated to investigate their conformity to the golden ratio. In this study, cases were classified into 4 groups based on the mean (XX) of each evaluated ratio, considering the corresponding standard deviation (SD) (Sertel Meyvacı *et al.*, 2021).

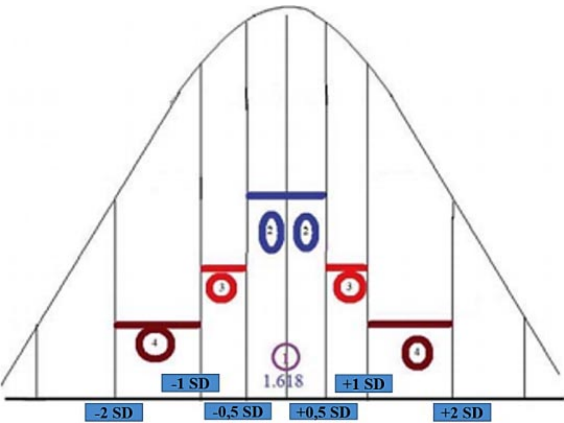


Fig. 1. Groups formed based on deviations from the mean of the evaluated ratios.

Table I. Description of anatomic parameters of the atlas.

Parameters	Definition
P1	Maximum transverse diameter
P2	Maximum anteroposterior diameter
P3	Transverse diameter of vertebral foramen
P4	Anteroposterior diameter of vertebral foramen
P5	The inner diameter of the transverse foramen
P6	The outer diameter of the transverse foramen
P7	Maximum anteroposterior diameter of the right superior articular surface
P8	Maximum anteroposterior diameter of the left superior articular surface
P9	Minimum mediolateral diameter of the right superior articular surface
P10	Minimum mediolateral diameter of left superior articular surface
P11	Maximum anteroposterior diameter of the right inferior articular surface
P12	Maximum anteroposterior diameter of left inferior articular surface
P13	Minimum mediolateral diameter of the right inferior articular surface
P14	Minimum mediolateral diameter of left inferior articular surface
P15	Maximum distance between the lateral edges of the superior articular surfaces
P16	Minimum distance between the lateral edges of the superior articular surfaces
P17	Maximum distance between the lateral edges of the inferior articular surfaces
P18	Minimum distance between the lateral edges of the inferior articular surfaces
P19	Height of the anterior arcus
P20	Height of the posterior arcus
P21	Diameter of the anterior arcus
P22	The diameter of the posterior arcus

- The first group included cases that were exactly aligned with the golden ratio (1.618).
- The second group comprised cases within a range of ± 0.5 standard deviations from the mean ratio (XX-0.5 SD to XX+0.5 SD).
- The third group included cases with deviations from the golden ratio between ± 0.5 SD and ± 1 SD (at least 0.5 SD and at most 1 SD away).
- The fourth group consisted of cases with deviations between ± 1 SD and ± 2 SD from the golden ratio (at least 1 SD and at most 2 SD away).

The classification of these groups is graphically summarized in Figure 1.

A total of 22 parameters previously defined as atlas-specific (Sertel Meyvacı *et al.*, 2024); were measured on facial CBCT images, and 57 ratios were calculated based on these measurements.

Measurement of Parameters

The parameters were measured in millimeters (mm) on multiplanar and three-dimensional CBCT images using predefined reference points, with measurements recorded to one decimal place. The description of the 22 parameters used in this study are provided below (Table I).

The ratios calculated using the 22 measured parameters are as follows:

1) P1/P2, 2) P1/P5, 3) P1/P15, 4) P1/P17, 5) P4/P16, 6) P4/P18, 7) P5/P3, 8) P5/P4 9) P6/P17 10) P7/P9 11) P7/P11 12) P7/P13 13) P7/P19 14) P7/P20 15) P7/P22 16) P8/P10 17) P8/P12 18) P8/P14 19) P8/P19 20) P8/P20 21) P8/P22 22) P9/P21 23) P9/P22 24) P10/P21 25) P10/P22 26) P11/P21 27) P11/P22 28) P12/P21 29) P12/P22 30) P13/P21 31) P13/P22 32) P14/P21 33) P14/P22 34) P15/P3 35) P15/P4 36) P16/P9 37) P16/P10 38) P16/P11 39) P16/P12 40) P16/P13 41) P16/P14 42) P16/P19 43) P16/P20 44) P17/P3 45) P17/P4 46) P18/P9 47) P18/P10 48) P18/P11 49) P18/P12 50) P18/P13 51) P18/P14 52) P18/P19 53) P18/P20 54) P19/P21 55) P19/P22 56) P20/P21 57) P20/P22

These calculated ratios were used to evaluate the proportional relationships among atlas parameters and to determine their conformity to the golden ratio. Each ratio was compared with the golden ratio value of 1.618, and deviations from this value were subsequently analyzed statistically.

Statistical Analysis

Descriptive statistics were calculated for the measurements and derived ratios, including mean, standard deviation (SD), median, 25th and 75th percentiles, counts, and percentage frequencies where appropriate. The normality of the data was assessed using the Kolmogorov–Smirnov test. The deviation of each calculated ratio from the golden ratio value of 1.618 was analyzed using the One-Sample t-test. In addition, individuals were classified into groups according to their deviation from the golden ratio at 0.5 SD, 1.0 SD, and 2.0 SD levels. The sex distribution of these deviation groups was then examined. The Pearson chi-square test was used to compare males and females in terms of their distribution across the deviation groups. A p-value of ≤ 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 29.

RESULTS

The individuals included in the study were aged between 18 and 82 years, with a mean age of 40.1 ± 16.7 years. The study population consisted of 180 males and 179 females. A total of 57 ratios were calculated based on the obtained measurements. Descriptive statistics for these ratios in the overall study population are presented in Table II. Using the SD values provided in this table, deviation ranges from the golden ratio value of 1.618 were determined at ± 0.5 SD, ± 1.0 SD, and ± 2.0 SD levels. Values outside the ± 2.0 SD range were classified as a separate group.

When examining whether the 57 ratios significantly deviated from the reported golden ratio (1.618), it was found that only the P9/P22 and P18/P14 ratios did not show a statistically significant deviation, whereas all other ratios exhibited a significant deviation (Table III).

In Table III, the mean difference column presents the average deviation of each calculated ratio from the golden ratio. Positive mean difference values indicate that the calculated ratio is significantly greater than the golden ratio, whereas negative values indicate that the calculated ratio is significantly smaller than the golden ratio.

An analysis of the distribution of the 57 ratios at various SD levels around the golden ratio (1.618) was conducted. For each of the 57 calculated ratios, deviations from the golden ratio at 0.5 SD, 1.0 SD, and 2.0 SD were determined, and groups were formed accordingly. The distribution of these groups across all individuals is presented in Table IV. The groups consist of cases deviating by 0.5 SD, 1.0 SD, 2.0 SD, and those deviating more than 2.0 SD from the golden ratio. Notably, none of the ratios were found to be exactly equal to 1.618.

An analysis of the distribution frequencies of the 57 ratios at various SD levels around the golden ratio (1.618) in relation to sex differences was conducted. When the distribution of these ratio groups was examined, those with results that differed according to sex ($p > 0.05$) are presented in Table V.

Table V displays the distribution of SD deviation groups for each calculated ratio according to sex. Groups that exhibited statistically significant differences between sexes are indicated with completely different letters (a and b).

DISCUSSION

The golden ratio (ϕ or F) is a mathematical proportion that has been recognized for centuries, with numerous studies demonstrating that many structures in nature follow this principle (Mahakul & Agarwal, 2021). In the human body, this divine ratio has been associated with enhancing aesthetic perception and optimizing functional capacity (Iosa *et al.*, 2016). A study investigating the relationship between anthropometry and gait dynamics confirmed the hypothesis that physiological human gait follows the golden ratio in the proportionality of stance and swing phases. This finding supports the notion that the golden ratio naturally exists within the human body (Iosa *et al.*, 2016). Similarly, it has been demonstrated that the ratio of forearm length to hand length is also 1.618 (Stakhov & Sluchenkova, 2002).

Table II. Descriptive statistics of the calculated ratios.

	n	Mean	SD	Minimum	Maximum	25	Percentiles Median	75
P1/P2	359	1.697	0.103	1.426	2.000	1.627	1.691	1.761
P1/P5	359	1.713	0.092	1.333	2.253	1.659	1.711	1.769
P1/P15	359	1.664	0.120	1.373	2.053	1.575	1.660	1.740
P1/P17	359	1.785	0.103	1.505	2.154	1.714	1.787	1.847
P4/P16	359	1.875	0.237	1.244	2.571	1.733	1.875	2.022
P4/P18	359	1.965	0.238	1.242	2.837	1.796	1.969	2.125
P5/P3	359	1.483	0.126	1.021	2.000	1.402	1.474	1.556
P5/P4	359	1.443	0.125	0.943	2.195	1.369	1.441	1.516
P6/P17	359	1.385	0.101	0.811	1.715	1.329	1.388	1.445
P7/P9	359	1.332	0.161	0.972	2.059	1.220	1.316	1.429
P7/P11	359	1.246	0.127	1.000	1.683	1.150	1.233	1.318
P7/P13	359	1.478	0.166	0.971	1.960	1.364	1.467	1.579
P7/P19	359	1.248	0.192	0.806	1.923	1.111	1.227	1.355
P7/P20	359	1.509	0.270	0.900	2.957	1.310	1.470	1.667
P7/P22	359	1.509	0.270	0.900	2.957	1.310	1.470	1.667
P8/P10	359	1.300	0.159	0.843	1.827	1.200	1.286	1.411
P8/P12	359	1.264	0.122	1.000	1.810	1.176	1.250	1.341
P8/P14	359	1.440	0.156	0.939	1.917	1.323	1.435	1.545
P8/P19	359	1.233	0.192	0.794	1.833	1.111	1.196	1.333
P8/P20	359	1.490	0.270	0.813	2.880	1.313	1.467	1.667
P8/P22	359	2.124	0.500	1.042	3.825	1.750	2.077	2.460
P9/P21	359	1.685	0.320	0.970	2.867	1.462	1.667	1.900
P9/P22	359	1.637	0.434	0.808	3.273	1.304	1.565	1.943
P10/P21	359	1.747	0.326	0.909	2.720	1.538	1.714	1.947
P10/P22	359	1.691	0.418	0.818	3.545	1.400	1.643	1.962
P11/P21	359	1.795	0.331	1.061	2.773	1.542	1.769	2.000
P11/P22	359	1.735	0.411	0.818	3.455	1.438	1.688	2.000
P12/P21	359	1.747	0.326	0.909	2.720	1.538	1.714	1.947
P12/P22	359	1.691	0.418	0.818	3.545	1.400	1.643	1.962
P13/P21	359	1.520	0.302	0.828	2.688	1.300	1.500	1.700
P13/P22	359	1.470	0.369	0.738	2.545	1.188	1.417	1.700
P14/P21	359	1.537	0.292	0.839	2.333	1.320	1.500	1.714
P14/P22	359	1.488	0.373	0.738	2.550	1.217	1.429	1.731
P15/P3	3	1.529	0.133	1.093	1.945	1.448	1.518	1.620
P15/P4	359	1.489	0.138	1.102	2.293	1.394	1.485	1.583
P16/P9	359	1.566	0.245	1.000	2.500	1.400	1.528	1.700
P16/P10	359	1.547	0.235	1.074	2.439	1.375	1.525	1.683
P16/P11	359	1.468	0.233	1.000	2.857	1.303	1.447	1.591
P16/P12	359	1.508	0.222	1.023	2.609	1.360	1.487	1.625
P16/P13	359	1.739	0.278	1.209	3.333	1.549	1.710	1.882
P16/P14	359	1.715	0.257	1.200	3.226	1.528	1.686	1.857
P16/P19	359	1.469	0.275	0.897	2.645	1.267	1.425	1.616
P16/P20	359	1.781	0.436	0.900	6.000	1.500	1.700	1.988
P17/P3	359	1.423	0.119	1.092	1.800	1.340	1.431	1.500
P17/P4	359	1.385	0.122	1.098	2.195	1.303	1.378	1.464
P18/P9	359	1.494	0.242	0.862	2.444	1.341	1.474	1.625
P18/P10	359	1.476	0.231	0.926	2.370	1.324	1.471	1.615
P18/P11	359	1.399	0.219	0.933	2.762	1.250	1.391	1.524
P18/P12	359	1.437	0.211	0.903	2.522	1.310	1.429	1.550
P18/P13	359	1.661	0.284	1.075	3.222	1.465	1.636	1.814
P18/P14	359	1.638	0.263	1.097	3.118	1.455	1.606	1.778
P18/P19	359	1.398	0.251	0.755	2.444	1.225	1.375	1.538
P18/P20	359	1.695	0.401	0.957	5.800	1.455	1.636	1.875
P19/P21	359	1.794	0.275	1.157	3.000	1.600	1.754	1.955
P19/P22	359	1.748	0.443	0.877	3.500	1.402	1.692	2.040
P20/P21	359	1.501	0.291	0.714	2.400	1.308	1.467	1.667
P20/P22	359	1.445	0.334	0.762	3.000	1.207	1.400	1.662

Table III. Comparison of the calculated ratios against the golden ratio.

	t	df	P	Test Value = 1.618	95% Confidence Interval of the Difference	
				Mean Difference	Lower	Upper
P1/P2	14.413	358	<0.001	0.079	0.068	0.089
P1/P5	19.704	358	<0.001	0.095	0.086	0.105
P1/P15	7.183	358	<0.001	0.046	0.033	0.058
P1/P17	30.818	358	<0.001	0.167	0.156	0.178
P4/P16	20.504	358	<0.001	0.257	0.232	0.281
P4/P18	27.658	358	<0.001	0.347	0.323	0.372
P5/P3	-20.362	358	<0.001	-0.135	-0.148	-0.122
P5/P4	-26.615	358	<0.001	-0.175	-0.188	-0.162
P6/P17	-43.752	358	<0.001	-0.233	-0.243	-0.222
P7/P9	-33.717	358	<0.001	-0.286	-0.303	-0.270
P7/P11	-55.419	358	<0.001	-0.372	-0.385	-0.359
P7/P13	-16.062	358	<0.001	-0.140	-0.158	-0.123
P7/P19	-36.374	358	<0.001	-0.370	-0.389	-0.350
P7/P20	-7.665	358	<0.001	-0.109	-0.137	-0.081
P7/P22	-7.665	358	<0.001	-0.109	-0.137	-0.081
P8/P10	-37.942	358	<0.001	-0.318	-0.334	-0.301
P8/P12	-54.997	358	<0.001	-0.354	-0.366	-0.341
P8/P14	-21.595	358	<0.001	-0.178	-0.194	-0.161
P8/P19	-38.038	358	<0.001	-0.385	-0.405	-0.365
P8/P20	-8.948	358	<0.001	-0.128	-0.156	-0.100
P8/P22	19.148	358	<0.001	0.506	0.454	0.558
P9/P21	3.989	358	<0.001	0.067	0.034	0.101
P9/P22	0.824	358	0.410	0.019	-0.026	0.064
P10/P21	7.507	358	<0.001	0.129	0.095	0.163
P10/P22	3.295	358	0.001	0.073	0.029	0.116
P11/P21	10.159	358	<0.001	0.177	0.143	0.212
P11/P22	5.391	358	<0.001	0.117	0.074	0.160
P12/P21	7.507	358	<0.001	0.129	0.095	0.163
P12/P22	3.295	358	0.001	0.073	0.029	0.116
P13/P21	-6.142	358	<0.001	-0.098	-0.129	-0.067
P13/P22	-7.604	358	<0.001	-0.148	-0.186	-0.110
P14/P21	-5.254	358	<0.001	-0.081	-0.111	-0.051
P14/P22	-6.595	358	<0.001	-0.130	-0.168	-0.091
P15/P3	-12.663	358	<0.001	-0.089	-0.103	-0.075
P15/P4	-17.772	358	<0.001	-0.129	-0.144	-0.115
P16/P9	-4.032	358	<0.001	-0.052	-0.078	-0.027
P16/P10	-5.718	358	<0.001	-0.071	-0.095	-0.046
P16/P11	-12.153	358	<0.001	-0.150	-0.174	-0.125
P16/P12	-9.398	358	<0.001	-0.110	-0.133	-0.087
P16/P13	8.246	358	<0.001	0.121	0.092	0.150
P16/P14	7.167	358	<0.001	0.097	0.071	0.124
P16/P19	-10.273	358	<0.001	-0.149	-0.178	-0.121
P16/P20	7.081	358	<0.001	0.163	0.118	0.208
P17/P3	-31.047	358	<0.001	-0.195	-0.207	-0.183
P17/P4	-36.169	358	<0.001	-0.233	-0.245	-0.220
P18/P9	-9.743	358	<0.001	-0.124	-0.149	-0.099
P18/P10	-11.663	358	<0.001	-0.142	-0.166	-0.118
P18/P11	-18.972	358	<0.001	-0.219	-0.242	-0.196
P18/P12	-16.229	358	<0.001	-0.181	-0.203	-0.159
P18/P13	2.842	358	0.005	0.043	0.013	0.072
P18/P14	1.413	358	0.159	0.020	-0.008	0.047
P18/P19	-16.567	358	<0.001	-0.220	-0.246	-0.194
P18/P20	3.628	358	<0.001	0.077	0.035	0.118
P19/P21	12.100	358	<0.001	0.176	0.147	0.204
P19/P22	5.579	358	<0.001	0.130	0.084	0.176
P20/P21	-7.631	358	<0.001	-0.117	-0.147	-0.087
P20/P22	-9.827	358	<0.001	-0.173	-0.208	-0.139

Table IV. Distribution of ratios based on their deviation from the golden ratio.

SD range		%	n		%	n		%	n
± 0.5 SD range	P1/P2	114	31.8	P8/P20	121	33.7	P16/P12	116	32.3
0.5 - 1.0 SD range		90	25.1		104	29.0		108	30.1
1.0 - 2.0 SD range		114	31.8		117	32.6		112	31.2
+ 2.0 SD range		41	11.4		17	4.7		23	6.4
± 0.5 SD range	P1/P5	77	21.4	P8/P22	106	29.5	P16/P13	145	40.4
0.5 - 1.0 SD range		90	25.1		83	23.1		121	33.7
1.0 - 2.0 SD range		134	37.3		111	30.9		74	20.6
+ 2.0 SD range		58	16.2		59	16.4		19	5.3
± 0.5 SD range	P1/P15	136	37.9	P9/P21	146	40.7	P16/P14	155	43.2
0.5 - 1.0 SD range		99	27.6		100	27.9		107	29.8
1.0 - 2.0 SD range		102	28.4		94	26.2		77	21.4
+ 2.0 SD range		22	6.1		19	5.3		20	5.6
± 0.5 SD range	P1/P17	43	12.0	P9/P22	121	33.7	P16/P19	95	26.5
0.5 - 1.0 SD range		52	14.5		128	35.7		107	29.8
1.0 - 2.0 SD range		150	41.8		96	26.7		140	39.0
+ 2.0 SD range		114	31.8		14	3.9		17	4.7
± 0.5 SD range	P4/P16	67	18.7	P10/P21	144	40.1	P16/P20	185	51.5
0.5 - 1.0 SD range		84	23.4		97	27.0		98	27.3
1.0 - 2.0 SD range		152	42.3		92	25.6		60	16.7
+ 2.0 SD range		56	15.6		26	7.2		16	4.5
± 0.5 SD range	P4/P18	60	16.7	P10/P22	153	42.6	P17/P3	32	8.9
0.5 - 1.0 SD range		55	15.3		91	25.3		63	17.5
1.0 - 2.0 SD range		141	39.3		100	27.9		137	38.2
+ 2.0 SD range		103	28.7		15	4.2		127	35.4
± 0.5 SD range	P5/P3	72	20.1	P11/P21	136	37.9	P17/P4	26	7.2
0.5 - 1.0 SD range		74	20.6		101	28.1		28	7.8
1.0 - 2.0 SD range		150	41.8		86	24.0		136	37.9
+ 2.0 SD range		63	17.5		36	10.1		169	47.1
± 0.5 SD range	P5/P4	47	13.1	P11/P22	145	40.4	P18/P9	112	31.2
0.5 - 1.0 SD range		64	17.8		103	28.7		113	31.5
1.0 - 2.0 SD range		159	44.3		85	23.7		113	31.5
+ 2.0 SD range		89	24.8		26	7.2		21	5.8
± 0.5 SD range	P6/P17	11	3.1	P12/P21	144	40.1	P18/P10	105	29.2
0.5 - 1.0 SD range		17	4.7		97	27.0		107	29.8
1.0 - 2.0 SD range		105	29.2		92	25.6		116	32.3
+ 2.0 SD range		226	63.0		26	7.2		31	8.6
± 0.5 SD range	P7/P9	27	7.5	P12/P22	153	42.6	P18/P11	69	19.2
0.5 - 1.0 SD range		48	13.4		91	25.3		93	25.9
1.0 - 2.0 SD range		121	33.7		100	27.9		143	39.8
+ 2.0 SD range		163	45.4		15	4.2		54	15.0
± 0.5 SD range	P7/P11	8	2.2	P13/P21	120	33.4	P18/P12	93	25.9
0.5 - 1.0 SD range		9	2.5		108	30.1		90	25.1
1.0 - 2.0 SD range		45	12.5		115	32.0		132	36.8
+ 2.0 SD range		297	82.7		16	4.5		44	12.3
± 0.5 SD range	P7/P13	82	22.8	P13/P22	104	29.0	P18/P13	145	40.4
0.5 - 1.0 SD range		98	27.3		104	29.0		119	33.1
1.0 - 2.0 SD range		134	37.3		138	38.4		79	22.0
+ 2.0 SD range		45	12.5		13	3.6		16	4.5
± 0.5 SD range	P7/P19	31	8.6	P14/P21	120	33.4	P18/P14	148	41.2
0.5 - 1.0 SD range		29	8.1		107	29.8		113	31.5
1.0 - 2.0 SD range		111	30.9		116	32.3		86	24.0
+ 2.0 SD range		188	52.4		16	4.5		12	3.3
± 0.5 SD range	P7/P20	117	32.6	P14/P22	104	29.0	P18/P19	77	21.4
0.5 - 1.0 SD range		100	27.9		106	29.5		82	22.8
1.0 - 2.0 SD range		129	35.9		137	38.2		160	44.6
+ 2.0 SD range		13	3.6		12	3.3		40	11.1
± 0.5 SD range	P7/P22	117	32.6	P15/P3	105	29.2	P18/P20	172	47.9
0.5 - 1.0 SD range		100	27.9		96	26.7		122	34.0
1.0 - 2.0 SD range		129	35.9		117	32.6		53	14.8
+ 2.0 SD range		13	3.6		41	11.4		12	3.3
± 0.5 SD range	P8/P10	13	3.6	P15/P4	93	25.9	P19/P21	142	39.6
0.5 - 1.0 SD range		40	11.1		84	23.4		92	25.6
1.0 - 2.0 SD range		111	30.9		134	37.3		93	25.9
+ 2.0 SD range		195	54.3		48	13.4		32	8.9
± 0.5 SD range	P8/P12	5	1.4	P16/P9	135	37.6	P19/P22	135	37.6
0.5 - 1.0 SD range		10	2.8		119	33.1		115	32.0
1.0 - 2.0 SD range		52	14.5		87	24.2		91	25.3
+ 2.0 SD range		292	81.3		18	5.0		18	5.0
± 0.5 SD range	P8/P14	71	19.8	P16/P10	123	34.3	P20/P21	114	31.8
0.5 - 1.0 SD range		72	20.1		111	30.9		115	32.0
1.0 - 2.0 SD range		139	38.7		108	30.1		108	30.1
+ 2.0 SD range		77	21.4		17	4.7		22	6.1
± 0.5 SD range	P8/P19	26	7.2	P16/P11	99	27.6	P20/P22	102	28.4
0.5 - 1.0 SD range		28	7.8		108	30.1		110	30.6
1.0 - 2.0 SD range		102	28.4		126	35.1		126	35.1
+ 2.0 SD range		203	56.5		26	7.2		21	5.8

Table V. Distribution of groups showing various SD deviations from the golden ratio by sex.

	SD range	Male		Female		P
		n	%	n	%	
P1/P5	± 0.5 SD range	34	18.9	43	24.0	0.039
	0.5 - 1.0 SD range	37	20.6 ^a	53	29.6 ^b	
	1.0 - 2.0 SD range	73	40.6	61	34.1	
	+ 2.0 SD range	36	20.0 ^a	22	12.3 ^b	
P1/P17	± 0.5 SD range	16	8.9	27	15.1	0.001
	0.5 - 1.0 SD range	15	8.3 ^a	37	20.7 ^b	
	1.0 - 2.0 SD range	84	46.7	66	36.9	
	+ 2.0 SD range	65	36.1	49	27.4	
P4/P18	± 0.5 SD range	16	8.9 ^a	44	24.6 ^b	0.001
	0.5 - 1.0 SD range	32	17.8	23	12.8	
	1.0 - 2.0 SD range	70	38.9	71	39.7	
	+ 2.0 SD range	62	34.4 ^a	41	22.9 ^b	
P7/P19	± 0.5 SD range	12	6.7	19	10.6	0.014
	0.5 - 1.0 SD range	8	4.4 ^a	21	11.7 ^b	
	1.0 - 2.0 SD range	54	30.0	57	31.8	
	+ 2.0 SD range	106	58.9 ^a	82	45.8 ^b	
P8/P14	± 0.5 SD range	46	25.6 ^a	25	14.0 ^b	0.023
	0.5 - 1.0 SD range	31	17.2	41	22.9	
	1.0 - 2.0 SD range	62	34.4	77	43.0	
	+ 2.0 SD range	41	22.8	36	20.1	
P8/P19	± 0.5 SD range	7	3.9 ^a	19	10.6 ^b	0.008
	0.5 - 1.0 SD range	11	6.1	17	9.5	
	1.0 - 2.0 SD range	46	25.6	56	31.3	
	+ 2.0 SD range	116	64.4 ^a	87	48.6 ^b	
P16/P20	± 0.5 SD range	93	51.7	92	51.4	0.050
	0.5 - 1.0 SD range	55	30.6	43	24.0	
	1.0 - 2.0 SD range	29	16.1	31	17.3	
	+ 2.0 SD range	3	1.7 ^a	13	7.3 ^b	
P18/P19	± 0.5 SD range	28	15.6 ^a	49	27.4 ^b	0.050
	0.5 - 1.0 SD range	43	23.9	39	21.8	
	1.0 - 2.0 SD range	86	47.8	74	41.3	
	+ 2.0 SD range	23	12.8	17	9.5	

In a study testing, whether the lengths of metacarpal and phalangeal bones align with the Fibonacci sequence, conformity to the golden ratio was observed only between the metacarpal and proximal phalanx of the little finger. However, the absence of a similar relationship in other bones was attributed to differences in measurement techniques, specifically whether the measurements were taken along the joint line or through the center of joint rotation (Park *et al.*, 2003). The golden ratio has also been proposed to play a crucial role not only in the structural organization of human anatomy but also in the functioning of various body systems. For instance, the ratio of uterine length to width in a non-pregnant uterus has been reported to decrease with age, reaching its maximum value during the third decade of life, when fertility is at its peak. The observation that this ratio reaches 1.618 during this period, coinciding with the functional peak of the reproductive system, supports the idea that the golden ratio may serve as an indicator of biological

optimization in living systems (Verguts *et al.*, 2013). The heart, functioning in a highly synchronized and orderly manner within the human body, has increasingly become a subject of research from the perspective of the golden ratio (Yetkin *et al.*, 2013; Yetkin *et al.*, 2014; Papaioannou *et al.*, 2019). In a study conducted on healthy individuals with physiological electrocardiography data, the average diastole-to-systole ratio was found to be 1.61, while the cardiac cycle to diastole ratio was 1.62. These findings suggest that the rhythmic pattern of the heart muscle closely aligns with the golden ratio and indicate its potential utility as a diagnostic parameter in identifying certain pathological conditions (Yetkin *et al.*, 2013). In another study on the pulmonary system, it was reported that in individuals with pulmonary arterial hypertension and in the control group, fluctuations in systolic and diastolic pulmonary artery pressure exhibited a constant scaling factor corresponding to the golden ratio around the mean pulmonary artery pressure. This remarkable

characteristic provides a new perspective that could enable the examination of pulmonary hemodynamic processes within the context of the golden ratio (Chemla *et al.*, 2019). The golden ratio is not limited to the cardiovascular and pulmonary systems but has also been the subject of various studies in the auditory and craniofacial systems. The cochlea has drawn attention due to its spiral bony canal formation around the conical modiolus, resembling spiral structures in nature. Research has shown that the spiral structure of the cochlea aligns with the golden ratio, which optimizes sound perception efficiency and frequency tuning (Marinkovic *et al.*, 2012). A study on craniofacial ratios found that the ratio of the distance between the anterior nasal spine and the nasion to the height of the piriform aperture falls within the golden ratio range in male individuals (Sertel Meyvacı *et al.*, 2019). Moreover, Sarode *et al.* (2020), discovered that the oblique ridges of maxillary first molars and the triangular ridges of maxillary and mandibular premolars are divided into two segments following the golden ratio at the transverse and central grooves, respectively. The functional perfection of the occlusal table's strength and stability in posterior teeth has been attributed to the golden ratio. These findings provide new insights into the alignment of human facial proportions with the golden ratio.

In the present study, 57 ratios derived from different anatomical landmarks of the atlas were evaluated in relation to the golden ratio, considering its unique structure and critical role in the human body. The golden ratio was observed only in the P9/P22 ($p = 0.410$) and P18/P14 ($p = 0.159$) ratios. Nevertheless, the P1/P2, P1/P15, P9/P21, P10/P22, P12/P22, P18/P13, and P18/P20 ratios were also found to approximate the value of 1.618. These findings indicate that certain morphometric relationships within the atlas demonstrate a pattern consistent with the golden ratio, suggesting the presence of a distinctive geometric organization underlying its structural architecture. Evaluation of the ratios within the ± 0.5 SD interval revealed that 23 measurements clustered around the golden ratio. These ratios included P1/P2, P1/P15, P9/P21, P10/P21, P10/P22, P11/P21, P11/P22, P12/P21, P12/P22, P13/P21, P14/P21, P16/P9, P16/P10, P16/P12, P16/P13, P16/P14, P16/P20, P18/P13, P18/P20, P19/P21, P19/P12, and P20/P21. Furthermore, the notably high frequency values observed for the P18/P10, P18/P12, and P20/P22 ratios indicate that the proportional harmony of the atlas may not be limited to a few isolated measurements but may instead reflect a broader anatomical pattern.

In addition, comparison of atlas ratios according to sex revealed statistically significant differences in P1/P15, P1/P17, P4/P18, P7/P19, P8/P14, P8/P19, P16/P20, and P18/P19 ($p < 0.05$), suggesting that certain proportional relationships of the atlas may vary between male and female individuals.

Overall, although exact conformity to the golden ratio was observed in a limited number of ratios, the presence of numerous atlas ratios closely approximating 1.618 highlights the distinctive proportional organization of the atlas. These findings support the presence of a degree of aesthetic harmony and geometric order within the morphological architecture of the atlas, while also suggesting an underlying structural integrity that may be associated with the biomechanical and functional characteristics of the craniovertebral junction. Furthermore, the present study provides valuable morphometric reference data and offers new insights into the anatomical architecture of the atlas, thereby contributing to a deeper understanding of this unique vertebral structure.

CONCLUSION

In conclusion, the present study provides valuable data on the evaluation of the atlas in terms of the golden ratio in the Turkish population. The aesthetic appearance of the atlas, which is noticeable to the naked eye, is further supported by the proximity of many of its ratios to the golden ratio. With these characteristics, the atlas plays a crucial role in the functional anatomy of the neck, serving as the primary structure that connects the head to the vertebra and facilitating mobility and cervical movements.

MEYVACI, S. S.; ANKARALI, H.; BULUT, D. G.; CELIK, B. & TASKIN, B. Evaluación de la proporción áurea en el atlas y sus características anatómicas únicas. *Int. J. Morphol.*, 44(3):959-967, 2026.

RESUMEN: Este estudio tuvo como objetivo evaluar si ciertas proporciones morfométricas del atlas se ajustan a la proporción áurea mediante el análisis de puntos de referencia anatómicos y parámetros específicos de su morfología única. Se analizaron imágenes de tomografía computarizada de haz cónico de 359 individuos (180 hombres, 179 mujeres), de 18 a 82 años de edad, para evaluar los parámetros morfométricos del atlas. Se midieron 22 parámetros morfométricos del atlas y se calcularon 57 proporciones a partir de estas mediciones. Con base en el valor medio de cada proporción evaluada y la desviación estándar (DE) correspondiente, los casos se clasificaron en cuatro grupos. Se determinaron las estadísticas descriptivas de las mediciones y las proporciones calculadas, incluyendo la media, la DE, la mediana, los percentiles 25 y 75, el recuento y las frecuencias porcentuales. La desviación de las proporciones calculadas con respecto a la proporción áurea se examinó mediante una prueba *t* de una muestra. Entre las 57 proporciones calculadas, la proporción áurea se observó solo en P9/P22 ($p = 0.410$) y P18/P14 ($p = 0.159$). Varias otras proporciones tuvieron valores medios cercanos a 1.618, incluyendo P1/P2 (1.697 ± 0.103), P1/P15 (1.664 ± 0.120), P9/P21 (1.685 ± 0.320), P10/P22 (1.691 ± 0.418), P12/P22 (1.691 ± 0.418), P18/P13 (1.661 ± 0.284) y P18/P20 (1.695 ± 0.401); sin embargo, estas proporciones difirieron significativamente de la proporción áurea. Los hallazgos proporcionan información valiosa sobre la relación entre las proporciones morfométricas del atlas y la proporción áurea en esta muestra de población turca. Se observó que varias proporciones eran numéricamente cercanas a la proporción

áurea. Estos resultados proporcionan datos de referencia sobre la morfometría del atlas y sugieren que ciertas relaciones proporcionales del atlas pueden reflejar su organización anatómica distintiva.

PALABRAS CLAVE: Morfometría del atlas; Serie de Fibonacci; Proporción áurea; Simetría; Población turca.

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