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Morphological Measurement and Anatomical Variations of the Clivus Using Computed Tomography

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Abstract

Objectives The aim of this study was to evaluate the clivus morphology, including fossa navicularis magna (FNM), canalis basilaris medianus (CBM), and craniopharyngeal canal (CC), on computed tomography (CT) images.
Design This is a retrospective study.
Setting Faculty of Dentistry, Department of Dentomaxillofacial Radiology.
Participants The CT images of 500 patients (253 males; 247 females) were evaluated.
Main Outcome Measures The prevalence of FNM, CBM, and CPC; the length, width, and depth of FNM; and CBM types were recorded. Also, a morphological analysis of the clivus (length of the clivus, angle between the clivus and the posterior margin of the foramen magnum, angle between the clivus and the dens axis, and anteroposterior diameter of the foramen magnum) was performed.
Results FNM was identified in 5.4%, CBM in 4%, and CC in 0.8% of the study group. Type 5 CBM was not found. Type 6 was the most common CBM type. There was no significant correlation between the age and gender of patients with FNM. There were significant differences between the clivus length, the angle between the clivus and the dens axis, the anteroposterior diameter of the foramen magnum, and gender. Also, there was a significant difference between the angle between the clivus and the foramen magnum and age.
Conclusions The anatomical variations of the clivus are rare and important for the oral and maxillofacial radiologist to make the differential diagnosis. These anatomical variations should not be confused with pathologic formations. The morphological measurements and anatomical variations of the clivus can be evaluated in detail on CT images.

Keywords
- anatomical variation
- clivus
- computed tomography
- skull base

Introduction

The clivus is a bony surface whose name means "slope." Fusion of the basisphenoid and basioccipital bones creates the middle part of the skull base, and this fusion usually occurs before the age of 18 years.[1,2]

This study is concerned with three anatomical variations. Fossa navicularis magna (FNM) is an anatomical variation of the lower part of the clivus, as well as a notch in the basioccipital bone. In general, FNM is incidentally noticed in radiologic evaluations, and its cortical margins can be distinctly observed.[3]

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Fig. 1 Axial and sagittal measurements of fossa navicularis magna (FNM). The axial scan shows the width and the sagittal scan shows the length and depth of FNM.

Canalis basilaris medianus (CBM) is an uncommon anatomical variation that is defined as a cortical and well-defined canal between the nasopharynx and the intracranial surface of the basioccipital.[4] In the literature, six types of CBM have been identified: three complete types—superior, inferior, and bifurcated—and three incomplete types—long thin channel, superior recess, and inferior recess.[4,5]

Craniopharyngeal canal (CC) is a clivus anomaly defined as a well-corticated midline canal extending from the roof of the nasopharynx to the base of the sella.[6]

As morphological measurements of the clivus, its length, shape, and relationship with the foramen magnum and dens axis have been found to be significant in various clinical situations,[7] including coloboma (C), heart problems (H), closed posterior nostrils (A), growth retardation (R), insufficient genitalia development (G), and ear anomalies (CHARGE) syndrome; basilar invagination; platybasia; and Chiari malformation.[7–9] The aim of this study was to assess the morphological measurements and the anatomical variations of the clivus, including FNM, CBM, and CC, on computed tomography (CT) images, which are generally used for skull base and maxillofacial imaging to perform accurate and reliable evaluations.[1]

Materials and Methods

The Ethical Committee of the Hatay Mustafa Kemal University Faculty of Medicine approved this study (decision no. 15; February 27, 2020).

Images of the patients who were seen at the Department of Dentomaxillofacial Radiology were selected from the database. Patients with a history of skull base trauma or surgical operations and images with poor quality were excluded from the study. CT images of 500 patients (253 males [50.6%] and 247 females [49.4%]) who met the inclusion criteria were evaluated retrospectively.

Based on a study by Bayrak et al,[1] the depth, width, and height of FNM were measured (►**Fig. 1**); CBM was separated by type; and the prevalence of CC was calculated. The longest distance in the anteroposterior direction was measured as the length and the deepest part as the depth. The longest distance in the mediolateral direction was measured as the width.[1]

The well-defined, cortical and bony transclival defect found in the basioccipital of the clivus was defined as CBM and classified into six types (type 1–6; ►**Fig. 2**). CC was defined as a small canal extending from the sella turcica to the nasopharynx[1] (►**Fig. 3**).

Clivus morphological measurements were made, based on previous studies,[10–20] as follows: the length of the clivus, the angle between the clivus and the posterior margin of the foramen magnum, the angle between the clivus and the dens axis, and the anteroposterior diameter of the foramen magnum (►**Fig. 4**).

Length of the clivus: the longest distance superoinferiorly from the upper point of the dorsum sellae to a line drawn posteriorly to the end point of the clivus.

Angle between the clivus and the dens axis: the angle between the posterior surface of the clivus and the posterior surface of the dens axis.

Angle between the clivus and the foramen magnum: the angle between the line drawn along the posterior edge of the clivus and the posterior edge of the foramen magnum.

A 64-slice MDCT machine (Toshiba Aquilion, Toshiba Medical Systems, Otawara, Japan; 120 kV, 150 mA, 0.5-mm slice thickness) was used for all the CT procedures. A routine protocol was performed. First, axial plane images were obtained; after that, a multiplanar reformatting of the sagittal and coronal plane images was performed. The bone window CT scans were evaluated. All evaluations were made using a 15.6-inch full-HD notebook with a resolution of 1,920 × 1,080 pixels. A single blinded observer (G.S.), who

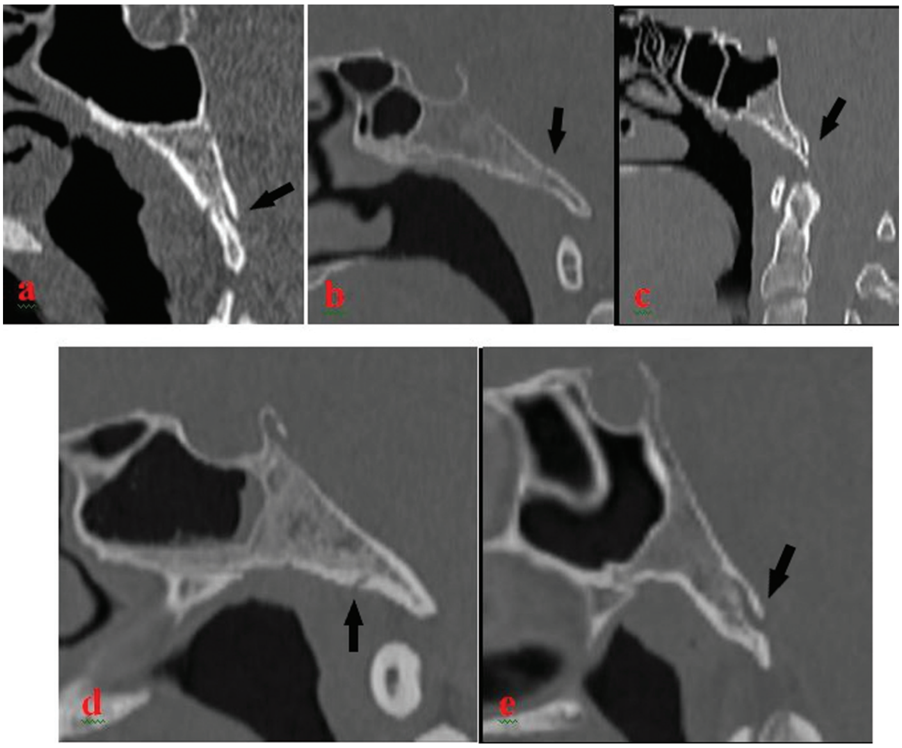

Fig. 2 Computed tomography (CT) images of canalis basilaris medianus (CBM) types in the study. (**a**) Type 1. (**b**) Type 2. (**c**) Type 3. (**d**) Type 4. (**e**) Type 6. Type 5 could not be observed in these study data.

was previously calibrated and had 6 years of clinical experience, evaluated all images twice with no information about the clinical situations of the patients. Intraobserver reliability was estimated using measurements made 1 week apart. Undecided situations were solved by consensus with K.G., who had nearly 15 years of clinical experience.

Statistical Analysis

SPSS (IBM SPSS, Turkey) version 26 for Windows (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. For normality testing of the data (depth, height, and width), a Shapiro–Wilk test was used; a p-value > 0.05 indicated that the data were normal. t-tests were used to compare the means of the data between genders.

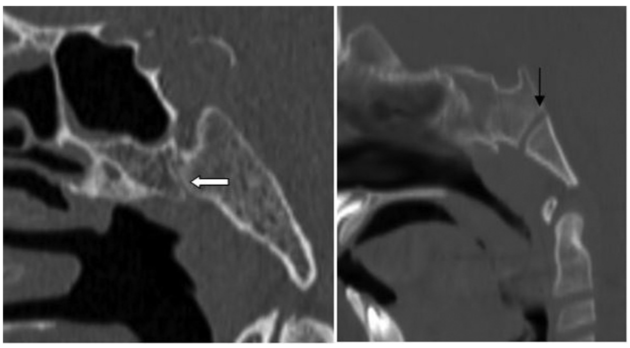

Fig. 3 Sagittal computed tomography (CT) scans of the craniopharyngeal canal (CC; *white arrow*) and the spheno-occipital synchondrosis (*black arrow*).

Normality (Shapiro–Wilk) tests of the clivus length, the angle at the clivus–dens axis, the angle between the clivus and the foramen magnum, and the foramen magnum anteroposterior diameter generated p-values lower than 0.05, so the distributions were not normal. A nonparametric method (Mann–Whitney U test) was therefore used. Correlations were calculated between the measurements and age. A correlation coefficient of 0 to 0.3 was considered weak, 0.3 to 0.5 was considered moderate, and greater than 0.5 was considered strong. The significance level was set at $p < 0.05$.

Results

Reliability was estimated by intraclass correlations (ICC) for all observations. Intraobserver ICC values for all measurements were excellent (ICC > 0.9).

The mean age of the participants was 39.53 years (SD $= 18.81$; range: 6–88). The mean age of the men in this study was 41.36 years (SD $= 19.61$; range: 6–88); the mean age of the women was 41.36 years (SD $= 17.79$; range: 7–84).

FNM was found in 27 cases (5.4%): 9 females (3.6%) and 18 males (7.1%). CBM was found in 20 cases (4%): 4 females (1.6%) and 16 males (6.3%). CC was found in four cases (0.8%): two females (0.8%) and two males (0.8%).

As shown in ►**Table 1**, correlations between gender and both FNM and CBM were weak. For the CC variable, this value was 0.980, indicating a strong correlation between this variable and gender.

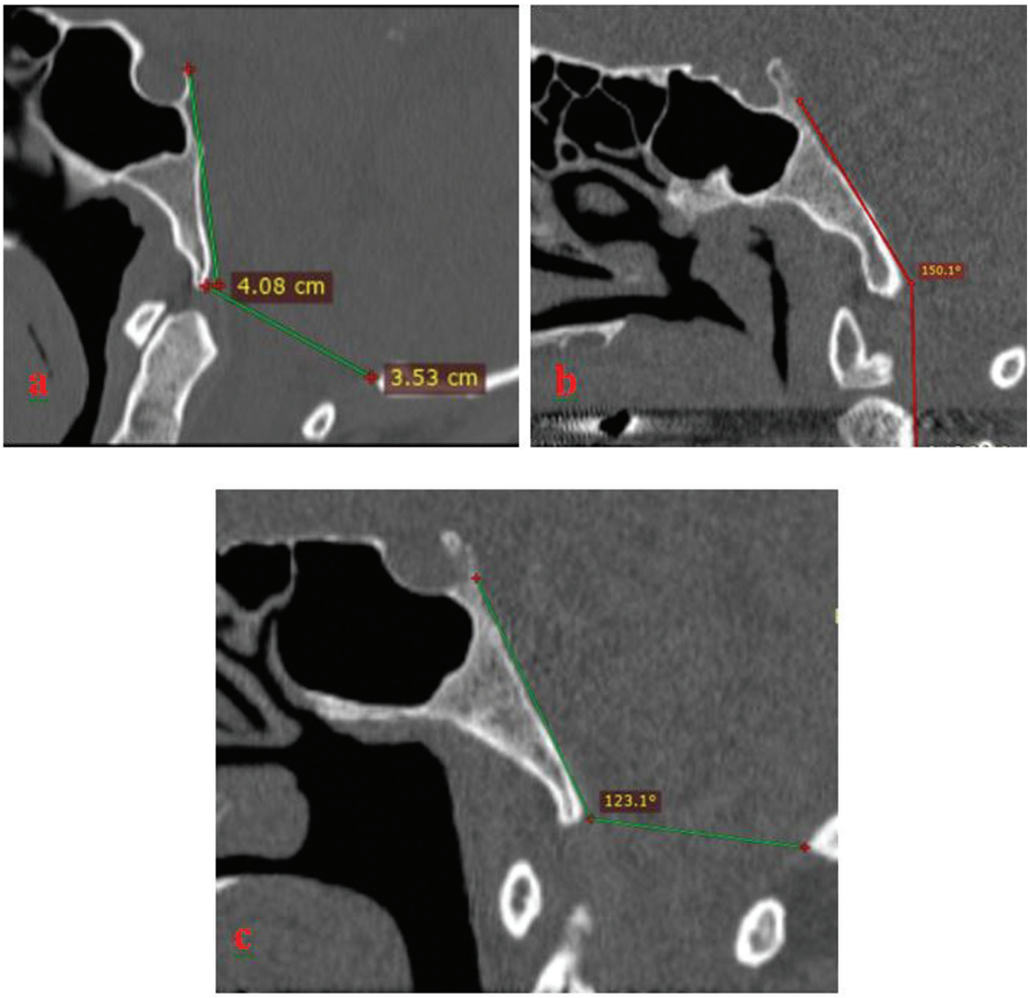

Fig. 4 The morphological measurements. (**a**) Length of the clivus, anteroposterior diameter of the foramen magnum. (**b**) The angle between the clivus and the dens axis. (**c**) The angle between the clivus and the foramen magnum.

Descriptive information on the depth, length, and width measurements from patients with FNM is given in ►**Table 2**. There was no significant relationship between the age or gender of the patients and the measurements of FNM ($p > 0.05$; ►**Table 3**).

Descriptive statistics of the types and frequencies of CBM are given in ►**Table 4**. Descriptive statistics of the morphological measurements and their frequencies by gender are given in ►**Table 5**. There was a significant difference between the clivus length, the angle between the clivus and the dens axis, the anteroposterior diameter of the foramen magnum, and gender ($p < 0.05$). Also, there was a significant difference between the angle between the clivus and the foramen magnum and age ($p < 0.05$; ►**Table 6**).

Discussion

Fossa Navicularis Magna

The frequency of FNM in this study (5.4%) was higher than that found in previous studies by Rossi[21] (1.5%; 55 of 3,712 dried skulls), Romiti[22] (0.9%; 9 of 990 skulls), Rizzo[23] (2.1%; 7 of 335 skulls), and Ray et al[24] (1.49%; 3 of 202 skulls). Cankal et al[25] reported frequencies of 5.3% (26 of 492 dry skulls) and 3% (16 of 525 CT images). However, Bayrak et al,[1] Ersan,[3]

Table 1 Testing the significance and correlation between gender and age in variables

Variable	Age (p-value)	Gender (phi-correlation)
Fossa navicularis magna	0.73	0.086
Canalis basilaris medianus	0.14	0.017
Craniopharyngeal canal	0.65	0.980

Note: The statistically significant level is $p < 0.05$.

Table 2 Descriptive information on the depth, length, and width of patients with fossa navicularis magna

	Gender	Numbers	Percent	Minimum–maximum	Mean ± SD
Depth	Female	9	33.33	1–7	3.77 ± 2.08
	Male	18	66.67	1–10	5.55 ± 2.87
	Total	27		1–10	4.96 ± 2.73
Length	Female	9	33.33	2–10	5.08 ± 3.19
	Male	18	66.67	1–5	3.12 ± 0.96
	Total	27		1–10	3.77 ± 2.15
Width	Female	9	33.33	3–4	3.40 ± 0.58
	Male	18	66.67	2–6	3.52 ± 1.13
	Total	27		2–6	3.48 ± 1.11

Table 3 The significance and correlation between gender and age in patients with fossa navicularis magna

Variable	Age		Gender (*p* value)
	Correlation	*p* value	
Depth	−0.030	0.88	0.111
Length	0.155	0.43	0.106
Width	−0.159	0.42	0.74

Note: The statistically significant level is $p < 0.05$.

Table 4 Descriptive statistics on the types and frequency of patients with canalis basilaris medianus

		Gender	Frequency	Percent	Mean
Canalis basilaris medianus	Type 1	Female	0	10	45
		Male	2		
	Type 2	Female	2	10	40.5
		Male	0		
	Type 3	Female	0	20	26.25
		Male	4		
	Type 4	Female	0	20	49.5
		Male	2		
	Type 5	Female	0	0	0
		Male	0		
	Type 6	Female	2	40	34.2
		Male	8		
	Total		20	100	

Kaplan et al,[26] and Magat[27] all reported higher frequencies than in the current study: 7.6, 6.6, 17.4, and 27.5%, respectively.

This study found an FNM depth of 4.96 ± 2.73 mm, width of 3.48 ± 1.11 mm, and length of 3.77 ± 2.15 mm. Cankal et al[25] reported an FNM depth of 2.24 mm, width of 2.85 mm, and length of 5.12 mm using a digital micrometer. Ersan[3] reported a depth of 2.2 mm, length of 5.8 mm, and width of 4.7 mm using cone beam CT measurements. Bayrak et al[1] reported that the mean depth, length, and width were 2.76 ± 1.09, 7.15–1.80, and 5.23 ± 1.57 mm, respectively, in cone beam CT images. They also reported that the mean depth, length, and width were 4.17 ± 0.54, 4.12 ± 0.52, and 4.08 ± 0.47 mm, respectively, in CT images. Similar to the study by Ersan,[3] there was no difference in the measurements of FNM between age groups.

Canalis Basilaris Medianus

The prevalence of CBM reported in the literature is 4 to 5% in children and 2 to 3% in adults.[28] The frequency of CBM in this

Table 5 Descriptive statistics on morphological measurements and their frequency based on genders of patients

Variables	Gender	Frequency	Minimum–maximum	Mean ± SD
Clivus length	Female	247	30–54	44.22 ± 3.94
	Male	253	34–55	46.19 ± 4.12
	Total	500	30–55	45.22 ± 4.15
Angle between the clivus and dens axis	Female	247	102–117	155.69 ± 10.86
	Male	253	116–179	154.00 ± 11.10
	Total	500	102–179	154.83 ± 11.01
Angle between the clivus and foramen magnum	Female	247	109–149	128.17 ± 7.93
	Male	253	106–154	129.20 ± 9.41
	Total	500	106–154	128.69 ± 8.72
Foramen magnum anteroposterior diameter	Female	247	22–53	31.97 ± 4
	Male	253	22–43	32.71 ± 3.91
	Total	500	22–53	32.35 ± 3.97

Table 6 The significance and correlation between gender and age in patients with morphological measurements

Variables	Age		Gender (*p* value)
	Correlation	*p* value	
Clivus length	–0.057	0.20	**0.000**
Angle between the clivus and dens axis	0.010	0.81	**0.022**
Angle between the clivus and foramen magnum	0.131	0.003	0.275
Foramen magnum anteroposterior diameter	–0.017	0.7	0.045

Note: The statistically significant level is $p < 0.05$.

study (4%) was higher than that in Bayrak et al[1] (2.5%) but lower than that in Kaplan et al[29] (4.3%). We found only one study[1] in the literature about the prevalence of CBM types that would allow a comparison. Bayrak et al[1] reported that types 1, 3, and 5 were the most common; however, in the current study, type 5 was not observed and type 6 was the most common. Further studies would be helpful in determining the prevalence of CBM types.

Craniopharyngeal Canal

Only a few studies were found in the literature regarding CC. The estimated incidence was 0.42%, and the majority of the cases were found in adults.[30] In the current study, the frequency of CC was 0.8%, whereas Bayrak et al[1] and Kaplan et al[29] reported the frequencies of CC as 0.3 and 5.4%, respectively.

Morphological Measurements of the Clivus

In the current study, the mean length of the clivus was 44.22 ± 3.94 mm in females and 46.19 ± 4.12 mm in males. Erçakmak Güneş and Vatansever[10] and Chaurasia et al[11] reported mean clivus lengths of 32.1 and 43.1 mm in females and 35.2 and 45.53 in males, respectively, whereas Basaran et al[12] reported a mean clivus length of 35.742 mm in measurements taken from magnetic resonance images of 50 healthy individuals. We think that the difference between the reported values is due to the different measurement methods.

The mean angle between the clivus and the dens axis was found to be 155.69 ± 10.86 degrees in females and 154.00 ± 11.10 degrees in males. Xu and Gong[20] reported that the mean angle was 135.8 ± 9.2 degrees in a control group and 110.4 ± 15.8 degrees in patients with basilar invagination, whereas Nagashima and Kubota[31] reported an angle of 157.4 ± 7.5 degrees in female patients and 158.2 ± 9.8 degrees in male patients on direct radiographs taken in a neutral position. Botelho and Ferreira[32] and Ferreira and Botelho[33] reported angles of 148 ± 9.88 and 148.50 ± 10.10 degrees, respectively, and Erçakmak Güneş and Vatansever[10] reported a mean angle of 140.61 degrees in female patients and 141.28 degrees in male patients. The results of the current study are therefore consistent with the literature.

This study found a mean angle between the clivus and the foramen magnum of 128.17 ± 7.93 degrees in females and 129.20 ± 9.41 degrees in males. Botelho and Ferreira[32] evaluated the craniovertebral junction magnetic resonance images of patients with chiari malformation and basilar invagination and a control group of healthy individuals; the mean angle in the control group was 126 ± 9.40 degrees, with a minimum of 103 degrees and a maximum of 148 degrees. In a study by Ferreira and Botelho,[33] the mean angle in the control group was 126.20 ± 9.68 degrees, whereas a study by Erçakmak Güneş and Vatansever[10] reported mean angles of 153.46 ± 9.13 degrees in females and 149.93 ± 8.60 degrees in males. The mean angles found in this study between the clivus and the foramen magnum are therefore consistent with the literature, except for Erçakmak Güneş and Vatansever,[10] who suggested that their higher values may be due to social and morphometric differences and that such larger angles should be considered in surgical approaches.

The mean anteroposterior diameter of the foramen magnum was 31.97 ± 4 mm in females and 32.71 ± 3.91 in males in this study. Erçakmak Güneş and Vatansever[10] and Madadin et al[16] reported mean diameters of 34.72 ± 2.57 and 36.10 ± 2.65 mm in females and 36.29 ± 2.89 and 37.21 ± 2.15 mm in males, respectively, on CT images.

FNM occurs close to the nasopharynx, clivus, and sphenoid sinuses, and various conditions should therefore be considered in the differential diagnosis of this anatomical variation, including local or metastatic tumors, adenoid retention cyst, adenoid hypertrophy, Rathke's sac cyst, Tornwaldt's cyst, sphenoid sinus mucocele, and dermoid teratoma of the posterior nasopharyngeal wall.[25] It is important to know the anatomy of bone variations in this area, as various pathologic lesions should be distinguished from this anatomical structure.[1]

There are two case reports[34,35] of FNM with clinical symptoms such as headache, fever, pain, and stiffness in the neck. These reports described infections that spread intracranially from the oropharynx to the base of the skull through FNM. Some studies[5,36,37] have also reported that CBM may be a route to developing meningitis. Also, it is possible to confuse a CBM with a fracture; correct CBM diagnosis is important.[38] Pinilla-Arias et al[39] concluded that persistence of CC is an uncommon variation that is generally associated with the etiology of the transsphenoidal encephaloceles. CC is an uncommon, but important, variation for diagnosing nasopharyngeal or midline skull base pathologies, and an exact diagnosis can prognosticate pituitary dysfunction, help decide surgical indications, and avoid iatrogenic hypopituitarism or cerebrospinal fluid leakage.[40]

Morphometric measurements of the structures related to the skull base are of great importance for clinicians and radiologists during diagnosis and treatment. Different results can be obtained with different measurement techniques or due to individual and social differences, and these differences should be considered during evaluations.[10]

Conclusion

In conclusion, it is important to know the anatomy of this region well to make a correct diagnosis and to distinguish pathologic lesions from anatomical formations. Insufficient information was found in the literature about the anatomical variations of the clivus. To the best of our knowledge, there is no comprehensive study in the literature that evaluates both anatomical variations and morphological measurements of the clivus together. We also consider it an advantage to evaluate so many parameters in a high number of images. Therefore, it is hoped that this study will be of benefit to the literature and future research.

Conflict of Interest
None declared.

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