Clinical Significance and Radiological Evaluation of Crista Galli: A CBCT Study

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SUMMARY

The present study aimed to determine the morphometric dimensions of crista galli (CG) with cone-beam computed tomography (CBCT), to evaluate its position relative to the cribriform plate (CP), and to examine the prevalence of pneumatized CG (PCG). CBCT images of 245 individuals aged 9-77 years were examined, retrospectively. The length, height and width of CG were measured. The position of CG relative to the CP was examined and was classified. The presence of PCG was investigated in coronal, axial and sagittal sections. CG was classified as type I, II and III, and PCG as type IP, IIP and IIIP.

PCG was detected in 5 (2.04%) of 245 patients. Type IP was observed in only 1 patient and type IIP in 4 patients. Type I CG was observed in 161 individuals (65.7%), and type II CG in 79 individuals (32.2%). Type III and type IIIP were not seen. The height, width and length of CG were 13.2 ± 2.4 mm, 4.3 ± 1.2 mm and 12.5 ± 1.7 mm, respectively. These values did not differ significantly by gender ($p>0.05$). PCG is an anatomical variation of the ethmoid bone. In our study, the prevalence of PCG was quite low compared to previous studies. Besides, this study showed that the length (7.8-17.6 mm), height (6.2-20 mm) and width (1.3-7.5 mm) of the CG are in a very wide range. Further research is needed to determine the morphometry of CG and to compare the prevalence of PCG effectively.

Key words: Anterior skull base surgery – Cone-beam computed tomography – Crista galli – Pneumatization

INTRODUCTION

Crista galli (CG) is a rooster-crest-shaped anatomical formation extending from the middle of the cribriform plate (CP) upwards. It is a useful anatomical point in anterior skull base surgery, as it creates a connection with the falx cerebri posteriorly (Akiyama and Kondo, 2020). CG develops embryologically from the ethmoid bone (Papadopoulou et al., 2021). For this reason, it was thought that CG pneumatization (PCG) originated from ethmoid air cells. However, the other more accepted theory is that it occurs due to increased aeration as a result of the expansion of the frontal sinus adjacent to it (Som et al., 2009; Turna et al., 2014). In addition to these theories, Poje et al. (2014) reported that they considered PCG as a true sinus with the definition of sinus crista galli.

Anatomic variations are frequently observed in the paranasal sinuses and sinonasal regions.

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Some of these variations are considered as predisposing factors for pathological conditions such as rhinosinusitis. PCG may contain normal upper respiratory tract mucosa. Because of this mucosal layer, it may cause other paranasal sinus pathologies to be seen in PCG (Marjanovic Kavanagh et al., 2020). Drainage between the PCG and neighboring paranasal sinuses occurs through the sinus ostia as in others. When there is an ostial obstruction, infection of the mucosa, formation of mucoceles, and related headache may occur (Mladina et al., 2017). In case reports, it has been reported that PCG may be complicated with processes similar to rhinosinusitis; headache is observed in the frontal region, resistance to drug therapy may be observed; therefore, surgical drainage is the preferred treatment. Transnasal endoscopic surgery is preferred for surgical drainage (Socher et al., 2013; Min and Kim, 2016). Detailed examination with radiological evaluation is essential for the correct planning of the surgical procedure and to prevent complications (Hajiioannou et al., 2010).

Nowadays, interest in PCG has increased due to both its clinical effects and some neurosurgical approaches. The reported prevalence of pneumatization varies widely (Mladina et al., 2017). In this study, it was aimed to determine the anatomical and morphometric dimensions of CG using cone-beam computed tomography (CBCT), to determine the prevalence of PCG, and to evaluate its position relative to the CP.

MATERIAL AND METHODS

CBCT images of 300 patients taken for various reasons in the Department of Oral and Maxillofacial Radiology were examined. High-quality CBCT images with a voxel size of 0.200 mm were included in the study. Exclusion criteria were the presence of pathology or surgical procedure, trauma history, craniofacial deformity or syndrome, and poor-quality images. Images of 55 individuals were excluded from the study, according to these criteria. Ethical approval was obtained from Izmir Katip Celebi University Non-Interventional Clinical Studies Ethical Committee (02.07.2020, IRB:834). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent is not necessarily due to the retrospective nature of this study.

All of the images used in the study were obtained using the CBCT (NewTom 5G, Quantitative Radiology, Verona, Italy) device operating at 110 kVp. Images with 15 × 12 cm FOV range and 0.200 mm voxel size were used. Images were analyzed by an oral and maxillofacial radiologist using NNT (NNT Software Version 9.1; NewTom; Italy) computer software.

Firstly, PCG was investigated in coronal, axial and sagittal sections; and, if there was pneumatization, where it originated was determined. Maximum CG height and width were measured in coronal sections and maximum CG length was measured in axial sections (Fig. 1).

In coronal sections, the position of CG relative to the CP was examined and confirmed in mid-sagittal sections. It was classified according to Hajiioannou's classification (Hajiioannou et al., 2010) (Fig. 2):

Type I – The base of CG and CP are at the same level.

Type II – Less than 50% of CG height is below CP level.

Type III – More than 50% of CG height is below the CP level.

In the case of pneumatization, this classification was made as IP, IIP, and IIIP.

All statistical analyses were performed in IBM SPSS Version 26. Kolmogorov-Smirnov test was used in order to determine data distribution. The independent samples t-test, Kruskal-Wallis test, and Mann-Whitney U test were used. Spearman's rho and Pearson correlation tests were used for evaluating the correlation between measurements and age. The level of significance (p-value) was accepted as 0.05.

RESULTS

The study group consisted of 245 individuals (Mean age: 37.5), 183 women and 62 men. PCG

was detected in 5 (2.04%) of 245 patients. Type IP (0.4%) was observed in only 1 patient and type IIP (1.6%) in 4 patients (Table 1). All of the individuals with PCG were women. PCG was not observed in men. One of the detected PCGs was associated with the ethmoidal sinus and four PCGs with the frontal sinus (Figs. 3, 4). Type I CG was observed in 161 individuals (65.7%), and type II CG in 79 individuals (32.2%). Type III and type IIIP were not seen.

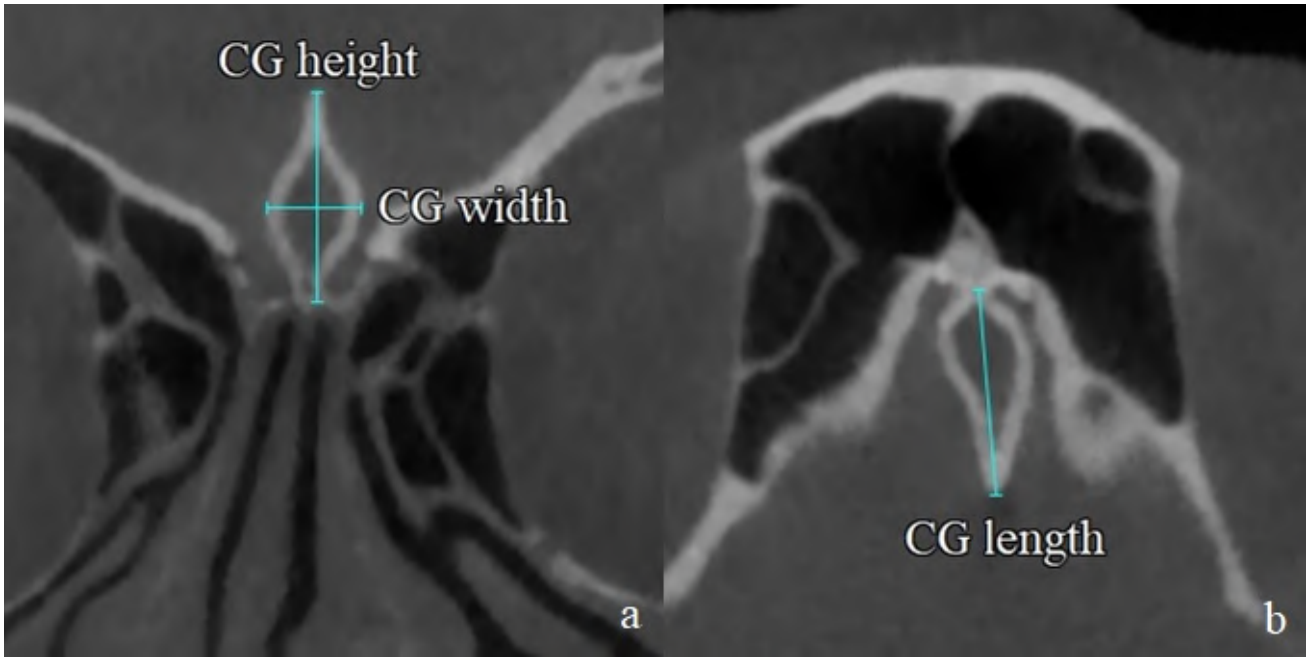

Fig. 1.- Measurements of crista galli (CG). (a) Measurement of height and width in coronal section, (b) Measurement of length in axial section.

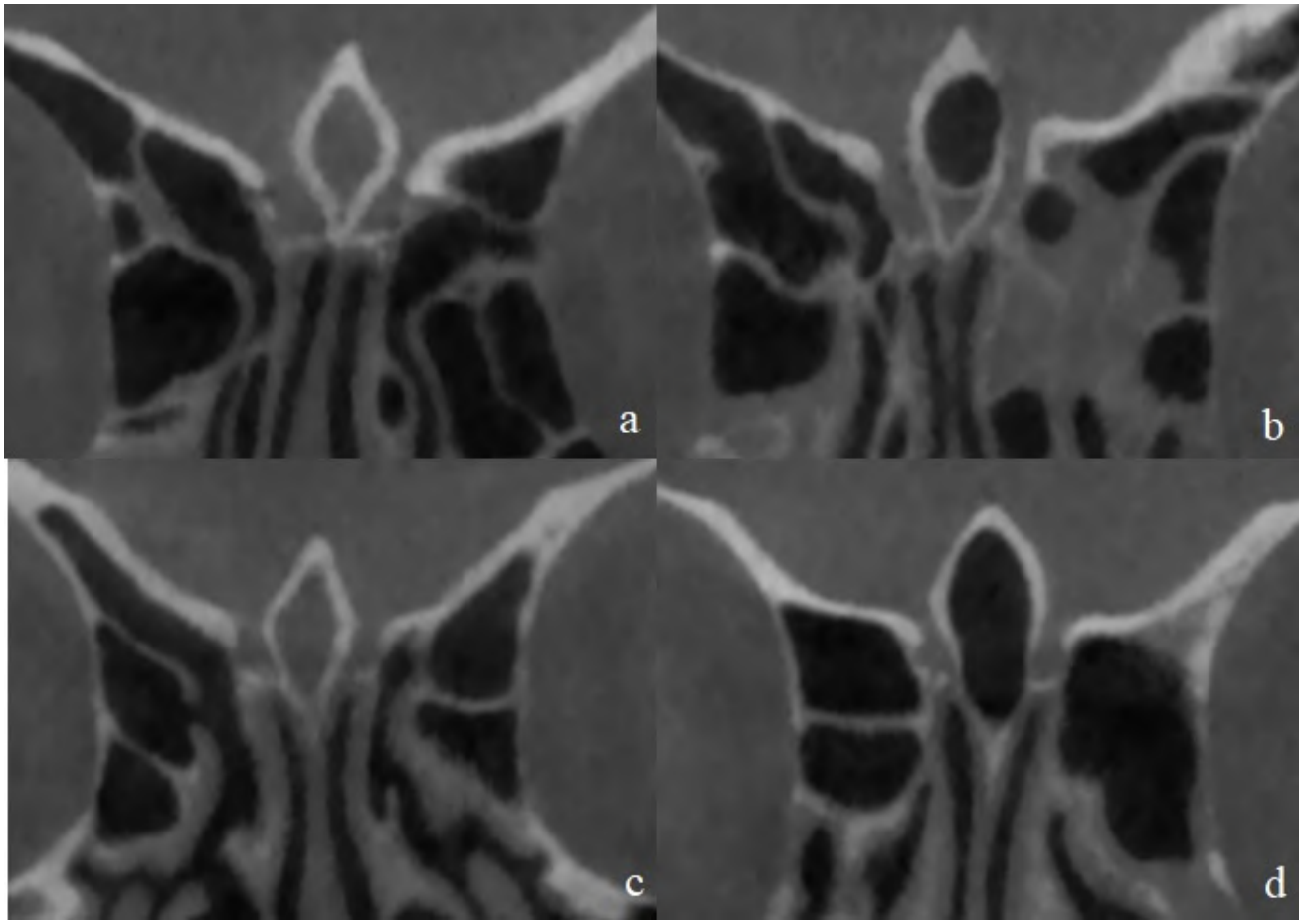

Fig. 2.- Sample images of the classification of crista galli. (a) Type I, (b) Type IP, (c) Type II, (d) Type IIP.

Table 1. Pneumatization and classification of crista galli

	Type I N (%)	Type II N (%)	Type III N (%)	Total N (%)
Pneumatization	1 (0.4)	4 (1.6)	0 (0)	5 (2.04)
Non-Pneumatization	161 (65.7)	79 (32.2)	0 (0)	240 (97.96)
Total	162 (66.1)	83 (33.8)	0 (0)	245 (100)

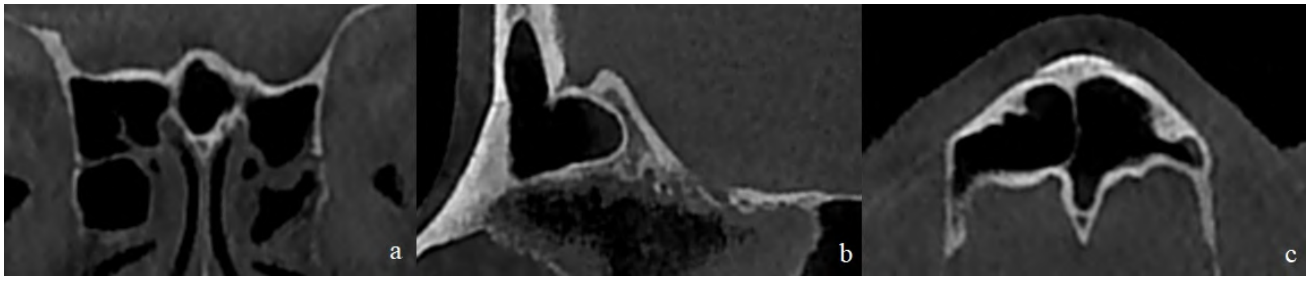

Fig. 3.- Pneumatized crista galli originating from the frontal sinus. (a) Coronal view, (b) Sagittal view, (c) Axial view.

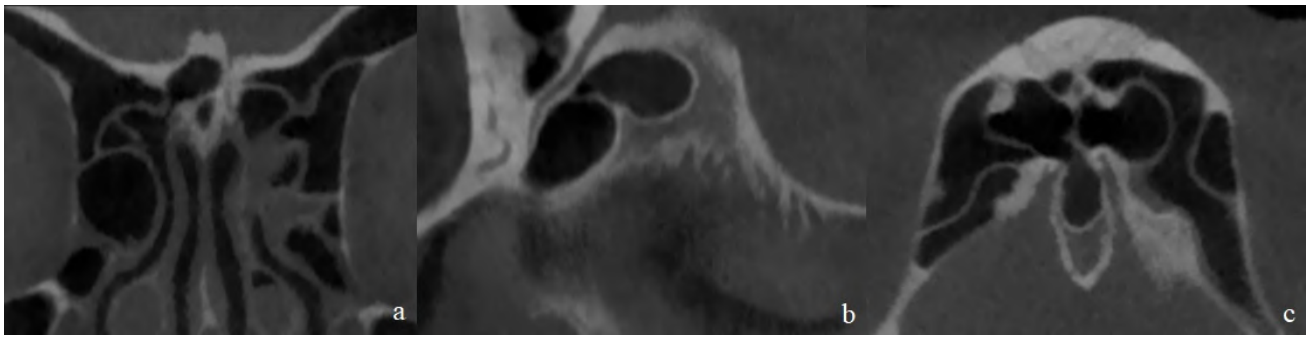

Fig. 4.- Pneumatized crista galli originating from the ethmoid sinus. (a) Coronal view, (b) Sagittal view, (c) Axial view.

Table 2 presents the height, length and width measurements of the CG. There was no significant difference in these values according to gender (p>0.05). In CGs without pneumatization, the heights in type I (N=161) and type II (N=79) were 12.6±2.2 and 14.3±2.5 mm, the widths were 4.1±1.2 and 4.5±1.1 mm, the lengths were 12.2±1.7 and 13.0±1.6 mm, respectively. There was a statistically significant difference between height, width, length values and the types of CG (Type I and Type II) (p=0.000, p=0.008, p=0.002). Type II CGs were larger than type I CGs.

Besides, it was investigated whether there is a correlation between the dimensions of CG and age. No statistically significant correlation was

Table 2. Measurement values of males, females and total

	Female (N:178)				Male (N:62)				Total (N:240)				
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	p-value
CG Height	13.2	2.4	6.2	19.8	13.1	2.5	8.0	20.0	13.2	2.4	6.2	20.0	0.647
CG Width	4.3	1.2	1.3	7.5	4.1	1.2	1.8	6.6	4.3	1.2	1.3	7.5	0.179
CG Length	12.4	1.7	7.8	16.1	12.7	1.6	9.8	17.6	12.5	1.7	7.8	17.6	0.289

CG: Crista galli, N: Number of patients, SD: Standard deviation, Min.: Minimum value, Max.: Maximum value.

found between the height, width and length of the CG and the age (r=0.093, p=0.148; r=-0.038, p=0.555; r=0.035; p=0.583).

DISCUSSION

CG is an important anatomical structure in endoscopic sinus and skull-base surgery (Metin-Tellioglu and Polat, 2019). This is due to its location, shape and dimensions. It projects superiorly into the intracranial space and is in contact with vital anatomical structures. The falx cerebri separating the right and left cerebral hemispheres connects to the CG. Besides, the CG is closely adjacent to the superior sagittal sinus. The superior sagittal sinus can start just in front of the CG. In the treatment of anterior skull base tumors, crista galli may need to be removed during endoscopic transcribriform surgery (Lee et al., 2011). Due to its location, there is a risk of injury to important vascular structures and leakage of cerebrospinal fluid (CSF) during surgery (Acar et al., 2020). It has been suggested that when pneumatization is present in the CG, it is more difficult to minimize CSF leak, and the surgeon should pay particular attention to the degree of pneumatization to prevent leakage. The location, dimensions and variations of CG should be well understood before surgery to avoid complications (Akiyama and Kondo, 2020).

PCG can include chronic sinusitis (Manea and Mladina, 2016), mucocele (Cervantes and Lal, 2014; Shidanshid et al., 2015), or dermoid cyst (Hajiioannou et al., 2010). In a histopathological study, PCG was detected in 5 out of 109 specimens. Chronic inflammation has been reported in all PCGs (Marjanovic Kavanagh et al., 2020). Recently, Takaki et al. (2021) reported that they detected erosion in CG with a dural arteriovenous fistula in a 38-year-old female patient. They suggested that external erosion of CG could be a sign of an aggressive dural arteriovenous fistula and should be carefully investigated. For this reason, CG should be examined, and the presence of PCG should be determined if present.

PCG was examined by various methods such as histopathological (Marjanovic Kavanagh et al., 2020), computed tomography (CT) (Som et al., 2009; Kim et al., 2012; Poje et al., 2014; Kamala et al., 2016; Metin-Tellioglu and Polat, 2019; Acar et al., 2020; Akiyama and Kondo, 2020) and CBCT (Mladina et al., 2017; Uçar et al., 2021). CBCT provides reliable and accurate measurements of bone structures in three axes. CBCT has advantages such as less radiation dose, shorter scanning time and low cost compared to CT (Scarfe et al., 2006; Ludlow and Ivanovic, 2008). For this reason, we preferred to use images obtained with CBCT in our study.

The prevalence of PCG reported in the literature ranges from 2.4% to 43% (Bašić et al., 1999; Som et al., 2009; Hajiioannou et al., 2010; Kaygusuz et al., 2014; Poje et al., 2014; Rereddy et al., 2014; Turna et al., 2014; Shpilberg et al., 2015; Dasar and Gokce, 2016; Manea and Mladina, 2016; Çalışkan et al., 2017; Devaraja et al., 2019; Metin-Tellioglu and Polat, 2019; Sommer et al., 2019; Acar et al., 2020; Akiyama and Kondo, 2020; Marjanovic Kavanagh et al., 2020; Uçar et al., 2021). In studies conducted in the Turkish population, the prevalence of PCG varies between 3.3 and 29.8% (Kaygusuz et al., 2014; Dasar and Gokce, 2016; Çalışkan et al., 2017; Sommer et al., 2019; Acar et al., 2020; Uçar et al., 2021). In our study, PCG was observed in only 5 patients (2.04%). It was a very low percentage, both according to studies in the same population and studies worldwide. A wide range of different PCG rates in the literature may have resulted from differences in racial, method and sample sizes.

Embryologically, since CG develops from the ethmoid bone, it makes sense for pneumatization to occur in the ethmoid complex. The pneumatization was thought to be caused by the ethmoid cells displaced to the frontal recess area (Som et al., 2009). However, it has been suggested that pneumatization may also originate from the frontal sinus immediately adjacent to the CG (Kim et al., 2012). Som et al. (2009) reported in their study that pneumatization in CG originated from the frontal sinus. Kim et al. (2012) reported that each pneumatization was associated with the frontal sinus, and that only one patient with bilateral undeveloped frontal sinuses had PCG connected to the ethmoid sinus. Kamala et al. (2016) found that 80% of PCGs originated from the frontal sinus and 20% from the ethmoid sinus. Akiyama et

Table 3. The distribution of crista galli's classification in previous studies

	Imagine Technique	Number of Patients	Type I (%)	Type II (%)	Type III (%)
Hajiioannou et al., 2010	CT	99	28.3	63.6	8.1
Kim et al., 2012	CT	818	13.9	84.2	1.8
Poje et al., 2014	CT	527	22.6	56.4	20.9
Kamala et al., 2016	CT	114	12.5	82.5	5
Acar et al., 2020	CT	402	18.3	64.9	16.8
Present Study	CBCT	245	66.2	33.8	0

al. (2020) detected 28 PCG (9.3%) in 300 patients, and reported that 17 of them originated from the frontal sinus and 11 from the ethmoid sinus. In our study, 4 of 5 PCGs detected were associated with the frontal sinus (80%), and 1 with the ethmoid sinus (20%). It is important to know whether the PCG originates from the frontal or ethmoid sinus in the selection of the surgical procedure to be applied. It has been reported that more care should be taken to prevent CSF leak and infection in PCGs associated with the ethmoid sinus (Akiyama and Kondo, 2020).

CG removal may be required during endoscopic anterior skull-base surgery, depending on the extent of the pathology. Given that the anterior ethmoid skull base is only a few millimeters thick, it is important to know the dimensions of the CG during this procedure (Lee et al., 2011). Mladina et al. (2017) reported the mean height, width and length of CG as 10.1 ± 3.1 mm, 3.0 ± 1.2 mm and 7.1 ± 2.5 mm, respectively. Akiyama et al.(2020) reported the mean height, width and length as 15.9 ± 3.2 mm, 4.9 ± 1.3 mm and 13.5 ± 2.8 mm, respectively. In our study, the mean height, width and length were 13.2 ± 2.4 mm, 4.3 ± 1.2 mm and 12.5 ± 1.7 mm, and these values did not differ significantly by gender. This study presented values in the middle of two previous studies that performed morphometric measurements of CG. We think that more studies with larger sample sizes are needed in order to define standard sizes and ethnic differences.

Hajiioannou et al. (2010) classified the position of CG in coronal and axial CT sections according to CP in their study. When examining the position of CG relative to CP, evaluating only in axial and coronal sections is insufficient, because CP is an inclined structure. Examinations performed together with the sagittal section will provide more accurate results. In addition, sagittal examinations are recommended to be performed in the median plane (Poje et al., 2014). Classification of the position of CG relative to CP was compared with previous studies, together with the imaging technique and the number of patients, in Table 3. The ratio of all CGs with or without pneumatization in the studies is given. A very different result was obtained compared to previous studies (Hajiioannou et al., 2010; Kim et al., 2012; Poje et al., 2014; Kamala et al., 2016; Acar et al., 2020). Type II was the most common in all of the studies. In our study, when all CGs were evaluated, surprisingly, type I (66.2%) was observed most frequently and type III was not observed. This difference may be due to the detection of CG types in coronal sections in our study and then confirmation in sagittal sections.

CONCLUSION

In conclusion, our study provided information about the morphology of CG, and found that PCG was observed at a low rate (2.04%) compared to previous studies. It was observed that the PCG originated mainly from the frontal sinus (80%). With a CBCT scan, the position of CG relative to CP and the relationship of CG with paranasal sinuses and other important anatomical structures can be determined, and this may be effective in providing safer surgical operations and preventing surgical complications. We think that further research with the large sample groups is necessary to determine the morphometry of CG and to compare the prevalence of PCG effectively.

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