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ORIGINAL ARTICLE

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Posterior ethmoid sinus: a computed tomography analysis and classification

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Abstract

Background: The CT details of the dimensions of the posterior ethmoid sinus are not fully covered in the literature, so building up for a base for the CT measurements and description of that area is important. Preoperative details of the posterior ethmoid sinuses are mandatory before any approach or procedure involving this area**.**

Objective: To determine the different dimensions, measurements, and grading of the posterior ethmoid sinus by computed tomography (CT) that were not previously published.

Methods: Two hundred paranasal CT scans (400 sides) were included in the study. Axial images were acquired with multiplanar reformats to obtain delicate details in coronal and sagittal planes for all subjects.

Results: Within 200 CTs (400 sides), the mean anteroposterior dimension of the posterior ethmoid was 13.62± 1.75 mm (range= 9.5–19.5), the mean posterior ethmoid transverse diameter was 12.15+1.6 mm (range= 8–16.2) and the mean posterior ethmoid height was 44.64±3.83 mm (range= 35.8–56) without reported significant differences between both sides in all posterior ethmoid dimensions. The mean width of the posterior ethmoid sinus and its height from the orbital roof and nasal floor was significantly more in males than in females. There was significantly lower fovea ethmoidalis in males than females as we go posterior.

Conclusion: This study improves surgeons' awareness and orientation of posterior ethmoid sinus variations in the endoscopic sinus surgery and can be of help to residents in training.

Keywords: Posterior ethmoid, Nose, Maxillary sinus, Skull base, Orbit, Computed tomography

Background

Endoscopic sinus surgery (ESS) is nowadays one of the most performed surgeries in otorhinolaryngology [1–3]. With the development of imaging modalities, endoscopic technologies, and equipment, ESS has gained popularity and extended beyond the nasal cavity and paranasal sinuses, and complications of ESS have been encountered [4–6]. Therefore, preoperative computed tomography (CT) evaluation is essential to identify the anatomical landmarks and dimensions of the paranasal sinuses, relations to their surrounding structures, and to assess the exact extension of the disease in order to gain a safe and effective surgical outcome [7–9]. However, in certain situations like trauma, neoplastic disorders, or even in revision cases, these landmarks may be distorted or even absent, making the dissection more difficult with a higher possibility and risk of complications. Therefore, the necessity to identify dimensions of the sinus preoperatively and its landmarks is of paramount importance. Also, these landmarks should be easily found and should guide the surgeon when he proceeds posteriorly [10].

The posterior ethmoidal sinus is one of the posterior groups of paranasal sinuses. Its framework may be altered due to various inflammatory or expansible lesions. The clinical significance of the posterior ethmoid lies in

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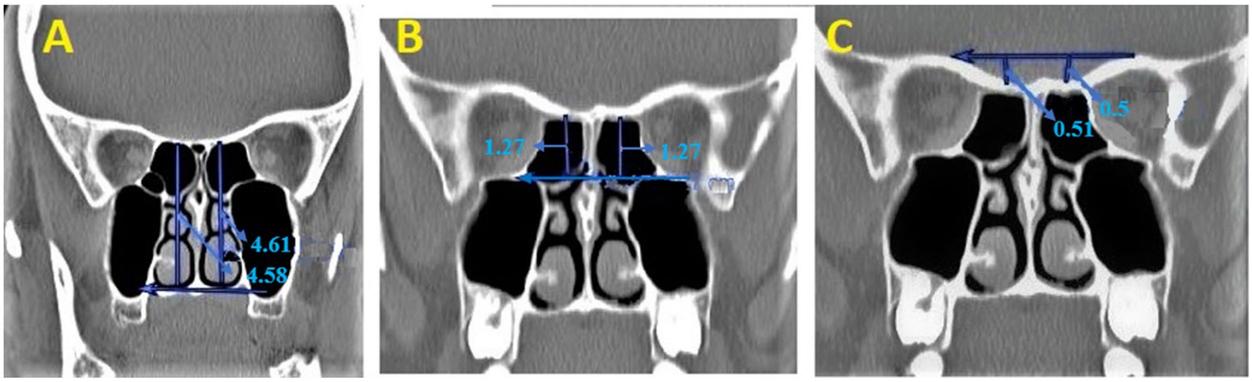

Fig. 1 CT coronal view shows th measurement of the height of the roof of the posterior sinus. **A** Height from the floor of the nose. **B** height from the roof of the maxillary sinus. **C** Distance from the orbial roof

its several relations and boundaries with the adjacent important structures like the orbit laterally (with closer relation to orbital muscles and the optic nerve than the anterior ethmoid sinus), the skull base superiorly, and the sphenoid sinus posteriorly [11, 12].

The bony posterior ethmoid sinus structures are used as landmarks in the management of various pathological processes encountered in the paranasal sinuses. Therefore, the proper preoperative posterior ethmoid cells evaluation in the surgical management of viscerocranial disease, including modern imaging techniques such as computed tomography (CT), is mandatory to provide adequate comprehension of the patient's facial skeleton.

Although the posterior ethmoid sinus is a frequent part of the surgery during ESS, to the best of our knowledge, the CT details and normal CT dimensions of the posterior ethmoid cells are missed in the literature, so building up for a base for the CT evaluation and description of that area is important. In addition, preoperative details of the posterior ethmoid cells are mandatory before any approach or operation involving or passing through this sinus.

Therefore, the present study aimed to determine the different dimensions, measurements, and grading of the posterior ethmoid cells that were not previously published. The results of the study may influence the surgery of the posterior ethmoid cells, especially the endoscopic approach.

Methods

This retrospective study was conducted on 200 CTs of paranasal sinuses (400 sides) at the Otorhinolaryngology and the Radiodiagnosis departments in a tertiary teaching hospital during the period between January 2019 and April 2020. The institutional review board approved the research methodology. The study was conducted according to the declaration of Helsinki on Biomedical Research Involving Human Subjects. Informed written consent was signed by all subjects to share in the study after an explanation of its purposes. Exclusion criteria include patients younger than 12 years, history of trauma or surgery in the paranasal sinuses or the skull base, congenital anomalies, fibro-osseous lesions of the paranasal sinuses, and/or malignancies.

CT examinations were performed for all the included patients with a 64-slice CT scan (Light speed volume VCT, GE medical system, Milwaukee, WI, USA). The protocol of 64-slice MDCT was performed with a 0.625-mm detector width, a 1.5-mm section width, and a 0.5-mm interval reconstruction.

Axial images were made covering the paranasal sinuses. The subject was studied in supine position and the beam was parallel to the hard palate. The cuts started from the hard palate to the frontal sinus (glabella) using 130 KV and 150 mA/s with 1.5 s scan time. Examinations were conducted with a bone window setting of 3000 HU, centered at 700 HU. A high-resolution algorithm was utilized to enhance the appearance of the delicate bony details.

Multiplanar reconstructions with delicate details in coronal and sagittal planes were obtained for all subjects at a dedicated post-processing workstation (Advantage Windows Volume share 4.5, GE Medical System, Milwaukee, WI, USA). Films were reviewed in a routine standardized manner in order not to miss small details.

A posterior ethmoid evaluation was performed in all patients along the axial, coronal and sagittal planes. Then, anatomical landmarks were used to take the posterior ethmoid measurements [1] (Figs. 1, 2, and 3).

All the dimensions of the posterior ethmoid sinus, anero-posterior (AP), transverse, and height, were measured. In the sagittal view, the AP (length of the posterior ethmoid) was measured at the widest

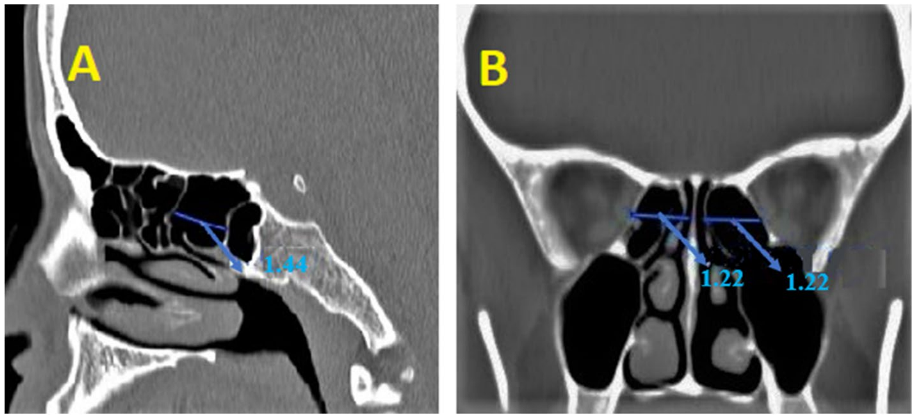

Fig. 2 **A** Sagital CT show measurement other anteroposterior dimension. **B** Coronal CT shows the measurement of the transverse dimension of the posterior ethmoid sinus

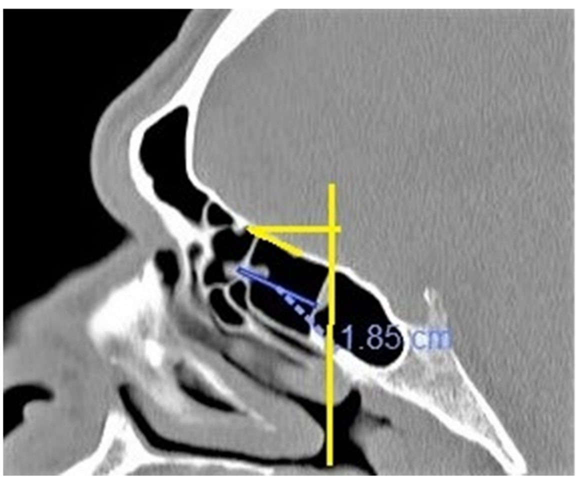

Fig. 3 Measurement of the degree of inclination of the posterior ethmoid sinus

distance between the posterior end of the posterior ethmoid (anterior wall of the sphenoid sinus) and the anterior end of the posterior ethmoid sinus (vertical part of basal lamella). The transverse diameter (width) of the posterior ethmoid sinus was measured in its widest area between the lamina and medial boundary. The transverse, AP, and height diameters of the posterior ethmoid sinus were categorized as; grade 1 (less than 10 mm), grade 2 (from 10 to 15 mm), and grade 3 (more than 15 mm).

In coronal view, the highest point of the orbital roof was identified on both sides, then the vertical distance between the midpoint of the roof of the posterior ethmoid sinus and a horizontal line passing between the highest point of the orbital roofs was measured to measure the height of the posterior ethmoid sinus from the orbital roof.

The vertical distance between the midpoint of the roof of the posterior ethmoid sinus and the floor of the nasal cavity was also measured in coronal view. In addition, after identification of the roof of the maxillary sinus, the midpoint of the posterior ethmoid sinus roof was identified on both sides. The vertical distance between the midpoint of the roof of the posterior ethmoid sinus and a horizontal line passing between the maxillary sinus roofs was measured.

The degree of posterior inclination of the roof of the posterior ethmoid sinus was recorded and categorized as; type 1 (<10°), type 2 (from 11 to 20°), and type 3 (> 20°).

Statistical analysis was conducted using SPSS (version 25; SPSS, Inc., Chicago, IL, USA). The *P* value of < 0.05 was considered statistically significant.

Results

A total of 200 CTs (400 sides) were included in the current study for 140 males (70%) and 60 females (30%). Their mean age was 31.69± 6.72 years (range: 17–49 years).

The mean AP diameter (length) of the posterior ethmoid sinus in both sides was 13.62± 1.75 mm (range= 9.5–19.5). The mean AP diameter on the right side was 13.28± 1.52 mm (range= 9.5–17.3), and 13.96±1.97 mm on the left side (range= 10.2–19.5) with non-significant difference between both sides (t=3.8649, p=0.68) (Table 1). The mean AP diameter in males was 13.61± 1.746 mm (range=9.5–18.4), and 13.645±1.9 mm in females (range= 10.2–19.5) without significant difference between both genders (t=0.23, p=0.8182) (Table 2).

The mean posterior ethmoid sinus width was 12.15±1.6 mm (range= 8–16.2). The mean width on

Table 1 Differences between the posterior ethmoid sinus dimensions at the right and left sides

		Right	Left	*P* value	
Angle (inclination)	**Mean**	12±3.89	12.32±4.27	0.5802	*T*=0.554
	Range	6–26	6–25		
Distance from orbital roof	**Mean**	4.79±0.75	4.93±0.78	0.1972	*T*= 1.2938
	Range	**3.7–7.8**	**3.7–8.5**		
Height fl	**Mean**	44.7±3.8	44.57±3.85	0.81	*T*=0.2403
	Range	**36.2–56.0**	**35.8–55.4**		
Height maxi	**Mean**	12.54±1.73	12.38±1.87	0.53	*T*=0.6281
	Range	**8.3–17.3**	**8.3–17.4**		
Width	**Mean**	12.06±1.58	12.24±1.62	0.4273	*T*=07954
	Range	**8–15.7**	**7.9–16.2**		
Length (AP)	**Mean**	13.28±1.52	13.96±1.97	0.68	*T*=2.7329
	Range	**9.5–17.3**	**10.2–19.5**		

Table 2 Differences between males and females

		Males 140 (280)	Females 60 (120 sides)	*P* value	
Angle	**Mean**	12.7±4.4	10.9±2.9	<0.0001	*T*=4.8263
	Range	6–26	6–17		
Height orb	**Mean**	4.9±0.8	4.7±0.6	0.0144	*T*=2.4577
	Range	3.7–8.5	3.7–6.5		
Height fl	**Mean**	45.767±3.66	42± 2.77	<0.0001	*T*=10.1
	Range	38.6–56	35.8–48.8		
Height maxi	**Mean**	12.6±1.86	12.1±1.6	0.0107	*T*=2.5655
	Range	8.3–17.2	9.6–17.4		
Width	**Mean**	12.3±1.69	11.8±1.296	0.004	*T*=2.8958
	Range	8–16.2	9.4–14.8		
Length (AP)	**Mean**	13.61±1.746	13.645±1.9	0.8182	*T*=0.23
	Range	9.5–18.4	10.2–19.5		

the right side was 12.06±1.58 mm (range= 8–15.7) and 12.24±1.62 mm on the left side (range= 7.9–16.2) with non-significant difference between both sides (t= 0.7954, p=0.4273). The mean width of the posterior ethmoid sinus was significantly more in males (12.3±1.69 mm) than in females (11.8±1.296 mm) (t=2.8958, p=0.004) (Table 2).

The mean vertical distance of the posterior ethmoid sinus roof from the orbital roof on both sides was 4.86±0.77 mm (range 3.7–8.5). The mean distance from the orbital roof on the right side was 4.79±0.75 mm (range= 3.7–7.8) and 4.93±0.78 mm on the left side (range 3.7-8.5) with a non-significant difference between both sides (t=1.2938, p=0.1972). The mean distance from the orbital roof in males was 4.9±0.8 (range= 3.7–8.5) and 4.7±0.6 in females (range= 3.7–6.5) with a significant difference between genders (t =2.4577, p=0.0144) (Table 2).

The mean height of the posterior ethmoid sinus from the nasal floor on both sides was 44.64±3.83 mm with a range 35.8–56. The mean height from the nasal floor on the right side was 44.7±3.8 with range 36.2–56.0. The mean height from the nasal floor on the left side was 44.57±3.85 with a range 35.8–55.4 with a non-significant difference between both sides (p= 0.81, t=0.2403). The mean height in males was 45.767±3.66 (range= 38.6–56) that was significantly more than the height from nasal floor in females (mean= 42± 2.77, range=35.8–48.8) (P <0.0001, t=10.1).

The mean height of the posterior ethmoid sinus from the maxillary sinus on both sides was 12.46±1.8 (range= 8.3–17.4). The mean height from the maxillary sinus on the right side was 12.54±1.73 (range= 8.3–17.3) and 12.38+1.87 on the left side (range= 8.3–17.4) with non-significant difference between both sides (p=0.53, t= 0.6281). The mean height from the maxillary sinus in males was 12.6±1.86 (range= 8.3–17.2), which was significantly higher than in females (mean= 12.1±1.6, range= 9.6–17.4) (P= 0.0107, t=2.5655).

All the dimensions, antro-posterior (AP), transverse, and height, were measured and categorized into 3 grades in which grade 1 is less than 10 mm, grade 2 is from 10 to 15 mm, and grade 3 is more than 15 mm (Table 3).

For the posterior ethmoid sinus height, grade I was detected in 8% of cases, grade II was reported in 84.5%, and grade III was in 7.5% of cases (Table 3).

For transverse diameter (width) of the posterior ethmoid sinus, grade I was detected in 9% of cases, grade II was reported in 86.5%, and grade III was in 4.5% of cases (Table 3).

Table 3 Grading for the different dimensions of the posterior ethmoid sinus and its incidence

Posterior ethmoid sinus	Percent
AP diameter	
Grade 1 (< 10 mm)	1%
Grade 2 (10–15 mm)	80.5%
Grade 3 (> 15 mm)	18.5%
Transverse diameter	
Grade 1 (< 10 mm)	9%
Grade 2 (10–15 mm)	86.5%
Grade 3 (> 15 mm)	4.5%
Height	
Grade 1 (< 10 mm)	8%
Grade 2 (10–15 mm)	84.5%
Grade 3 (> 15 mm	7.5%

AP antero-posterior

For the AP diameter (length) of the posterior ethmoid sinus, grade I was detected in 1% of cases, grade II was reported in 80.5%, and grade III was in 18.5% of cases (Table 3).

Degree of inclination (angle) of the posterior ethmoid sinus is as follows: type 1 (<10°) was found in 166 sides (41.5%) (88 right sides, 78 left sides), type 2 (from 11 to 20 degree) was found in 222 sides (55%) (106 right sides, 116 left), and type 3 (> 20 degree) was found in 12 sides (3%) (6 right sides and 6 left).

Degree of inclination in males was type 1 (<10°) in 100 sides (35.7%), type 2 (from 11 to 20°) in 168 sides (60%), and type 3 (> 20°) in 12 sides (4.3%).

Degree of inclination in females was type 1 (<10°) in 66 sides (55%) and type 2 (from 11 to 20°) in 54 sides (45%). While in females, type 3 (> 20°) was not detected. Thus, there is more posterior ethmoid sinus roof inclination angle and so significantly lower fovea ethmoidalis in males than females as we go posterior (p= 0.00032, X^2= 16.077).

Keross I was detected in 31%, Keross II in 60%, and Keross III in 9%. Keross classification was the same grade on both sides. The angle of inclination of the posterior ethmoid was found to be significantly correlated to the Keross classification (R= 0.308, P< 0001). So, when the Keross type becomes deeper, the posterior inclination of the posterior ethmoid sinus is more, so risky anterior ethmoid roof is associated with risky fovea ethmoidalis.

Onodi cell was found in 32 (16%) patients (24 males and 8 females): 14 at the right sides, 10 at the left sides, and 8 bilateral. In 24 males (5%), 10 Onodi cells were at the right sides, 8 at the left sides, and 6 were bilateral. While in 8 females (6.7%), 4 were on the right side, one was on the left side, and one was bilateral.

Regarding the relation between the anterior ethmoid roof (fovea ethmoidalis) and orbital roof, it was found that the fovea ethmoidalis could be found below the orbital roof in 136 (68%) (50 females + 86 males), at the same level of the orbital roof in 36 (18%) (8 females + 28 males), and above the orbital roof in 28 (14%) (2 females+ 26 males).

Discussion

The posterior ethmoid sinus (PES) is part of most ESS and the trans ethmoidal approaches are frequently used in extended and advanced ESS. Therefore, accurate determination of the dimensions and extensions of the posterior ethmoid sinus is highly important during basic and advanced ESS given its importance as an anatomical reference, and as an accessibility point (approach) for the skull base, lamina papyrecia (orbit), and sphenoid sinus.

Despite the widespread availability of teaching courses and the progress in ESS training, inefficient surgeries and complications are still a possibility [13], mainly the orbital and intracranial complications. In addition, efficient clearance of the ethmoid air cells on the LP remains a big challenge as residual pathology in the ethmoid cells on the LP is considered a common finding in revision FESS in up to 79% [14].

Endoscopic studies do not provide complete posterior ethmoid sinus localization and description for the operated patient as can do the preoperative CT. Thus, the preoperative CT assessment for posterior ethmoid sinus can provide the real and accurate posterior ethmoid sinus relations to the endoscopically detectable landmarks of each patient either pre or during the procedure.

Therefore, to perform a safe and effective surgery, reviewing the sinonasal CT anatomy is a critical step in the preoperative planning for ESS and the endoscopic sinus surgeons should be aware of CT sinonasal details [12].

Up to our knowledge, the radiological dimensions of the posterior ethmoid sinus were not previously published and the average dimensions of the posterior ethmoid sinuses are not available. In addition, most of the previously published studies utilized endoscopic measurements and landmarks for locating the posterior ethmoid sinus. Thus, the current study aimed to determine the different dimensions, measurements, and grading of the posterior ethmoid sinus that were not previously published. In addition, the results of the current study may influence the surgery of the posterior ethmoid sinus, especially the endoscopic approach.

In the current study, there were no reported significant differences between right and left posterior ethmoid sinuses in all the CT dimensions. The width of the posterior ethmoid sinus was significantly less in females, so more care of the lamina paperatea should be taken in females. While the posterior ethmoid sinus height was found to be significantly less in males, which could affect the skull base injury during FESS. It was found that there is more posterior ethmoid sinus roof inclination angle and so significantly lower fovea ethmoidalis in males as we go posterior.

We presented here a new classification (grades) for the transverse diameter of the posterior ethmoid sinus documenting that the most frequent grade of the lateral extension was grade 2 (10 to 15 mm). Additionally, we generated a grading of the height of the posterior ethmoid recording that the most frequent posterior ethmoid sinuses height type was grade 2 (10 to 15 ml). For the AP diameter of the posterior ethmoid sinuses, we offered a new grading for it verifying that grade 2 (10 to 15 ml) was the most frequent. Studying these grading before EES helps determine and predict the challenging sinus with higher potential of difficulties and complications, and may help in choices of the appropriate approaches for the skull base and the orbit.

It was also noted that the different posterior ethmoid dimensions showed significant variations reaching up to 2-folds between the least and longest range (9.5–19.5 mm for AP diameter, 7.9–16.2 mm for transverse diameter, and 35.8–55 mm for height from floor), which points to the importance of studying the CT dimensions of each posterior ethmoid cells before approaching it.

Up till now, there is no sufficient data in the literature regarding the relationship between the posterior ethmoid sinuses inclinations with Keros classification. That is why in the current study, we tried to add a detailed CT description of the posterior ethmoid sinuses and their relations to the surroundings.

In the current study, we found a significant correlation between the Keross classification and the angle of inclination of the posterior ethmoid, in which the deeper the Keross type, the more inclination of the posterior ethmoid sinus. This finding can aid in proper evaluation of the skull base level in the posterior ethmoid sinus minimizing the risk of CSF leak with its sequels

Thus, we presented a new grading to describe the accurate relation between the posterior ethmoid sinus to the neighboring structures that depend on precise CT measurements in living patients.

We believe that the grading systems presented in our study may help surgeons, especially those that do not have a navigation system in their centers as it is not usually found in most developing countries, to get a step forward in performing a safe and effective endoscopic work as it will give them an idea about the expected dimensions of the posterior ethmoid sinus and its relation to the orbit and the skull base, which will add to the safety and effectiveness of the operative outcome.

Moreover, the presented measurement, angles, and grading in our study may assist in building up a base on a new description of the posterior ethmoid sinus.

Moreover, it was reported that when the Keross type becomes deeper, the inclination of the posterior ethmoid sinus is more, so risky anterior ethmoid roof is associated with risky fovea ethmoidalis.

The grading system presented in our study gives surgeons an overview of the dimensions of the PES in the surgical field and the relation to the surrounding structures.

The current study puts basic data on the CT detailed description of the posterior ethmoid and updates the CT knowledge about the posterior ethmoid from a CT perspective in order to improve surgeons' and radiologist's awareness of posterior ethmoid in the endoscopic field for optimum and safe surgery. Studying the presented CT measures might help improve the operative plan and approach choice for disease involving this area or approached through it, and preparation for the instrument set required in each case.

In the current study, we could not compare our results and measurements with other studies because this data is scarce in the literature. Thus, studying the presented measurements and types of the posterior ethmoid is recommended in multi-center studies and different ethnic groups.

Conclusion

The current work updates the CT knowledge about the posterior ethmoid from a CT perspective in order to improve surgeons' and radiologist's awareness of PPF in the endoscopic field for optimum and safe surgery. Several new descriptions of the posterior ethmoid are presented here including all its dimensions, which might prove useful in the comprehension of the posterior ethmoid anatomy and surgery.

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Authors' contributions
MWE suggested and developed the research idea, reviewed the literature, statistical analysis, and revised the manuscript. RMA and DBE performed CT, collected data, reviewed the literature, wrote the methodology, revised the manuscript, and prepared the figures. AHE and AOK reviewed the literature, tabulated and interpreted the data, and wrote and revised the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The institutional review board of Faculty of Medicine, Zagazig University approved the research methodology. The study was conducted according to the declaration of Helsinki on Biomedical Research Involving Human Subjects. Informed written consent was signed by all subjects to share in the study after an explanation of its purposes.

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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