



ANATOMICAL VARIABILITY OF THE OLFACTORY FOSSA BASED ON KEROS CLASSIFICATION IN AN ADULT POPULATION

Bhawna sharma^{1*}, Dr Anjali Gopalrao Patil²

^{1*}, Research scholar, Dept.of Anatomy Index Medical college hospital & RC, Indore
Email ID: sharmabhnu11@gmail.com

², Associate Professor, Dept.of Anatomy Index Medical college hospital & RC, Indore
Email ID: anjaliptilpaode@yahoo.co.uk

***Corresponding Author:** Bhawana Sharma

*Research scholar, Dept.of Anatomy Index Medical college hospital & RC, Indore
Email ID: sharmabhnu11@gmail.com

Abstract

The olfactory fossa is one of the regions of the anterior skull base with the most anatomical diversity. Its depth, which is determined by the lateral lamella of the cribriform plate, is commonly classified using the Keros technique. Understanding this diversity becomes essential for accurate anatomical analysis and population-based assessment. In the present study 140 adult patients who had non-contrast paranasal sinus computed tomography at a tertiary care facility were included. On coronal CT scans, the depth of the olfactory fossa was assessed at its deepest point. The Keros categorization was used on both sides. SPSS was used for the statistical analysis, with a significance level of $p < 0.05$. The most common configuration was Keros Type II, which was followed by Type I and Type III. The bilateral symmetry was seen in the olfactory fossa, and there was no statistically significant difference between the two sides. A substantial variation in depth was noted on the left side, although gender-wise analysis revealed no significant correlation with Keros categorization. The study's objective is to assess the olfactory fossa's anatomical diversity in an adult population using Keros classification and related morphometric measures. In the adult population under study, Keros Type II is predominant. Regular side-based assessment with coronal CT improves knowledge of anterior skull base variability and yields useful morphometric data.

Introduction

One important part of the front skull foundation is the ethmoid bone, a delicate and intricate structure situated in the midline of the face skeleton. It is made up of two lateral labyrinths of air cells joined superiorly by a perpendicular plate, the crista galli, and the cribriform plate.^[1] The cribriform plate, lateral lamella, and fovea ethmoidalis, respectively, form the medial and lateral ceilings of the ethmoid labyrinth. Individual differences in the front skull base arrangement are caused by variations in the vertical extension of the lateral lamella.^[2-3] The cribriform plate of the ethmoid bone forms the floor of the olfactory fossa, an upright position near the front of the skull (Fig 1). It is surrounded medially by the crista galli and laterally by the lateral lamella of the cribriform plate. The depth of the olfactory fossa is mostly determined by the lateral lamella, which is the narrowest part of the anterior skull base. The olfactory fossa is considered one of the most

anatomically changeable areas of the anterior cranial base because of its structural delicacy and plasticity^[4] The lateral lamella of the cribriform plate's vertical height determines the olfactory fossa's depth (Fig 2). Keros outlined a three-category categorization scheme for the olfactory fossa based on this measurement. The depth ranges for Keros types I, II, and III are 1–3 mm, 4–7 mm, and 8–16 mm, respectively. The olfactory fossa is deeper and has a relatively thin lateral lamella in type III, whereas it is rather shallow in type I.^[5-7] An objective framework for evaluating the anatomical diversity of the anterior skull base is provided by the Keros classification. The bone structure of the anterior skull base may be precisely seen because to advancements in imaging, especially computed tomography with multiplanar reformations.^[8] The depth of the olfactory fossa, asymmetry of the ethmoidal roof, and morphometric differences of the lateral lamella can all be accurately assessed by computed tomography. Understanding population-based variability and structural trends in this area requires a thorough anatomical evaluation. Morphometric information in many groups is still scarce, despite the olfactory fossa's known diversity. The morphology of the anterior skull base in adults is better understood when its anatomical variations are systematically evaluated using defined categorization systems.

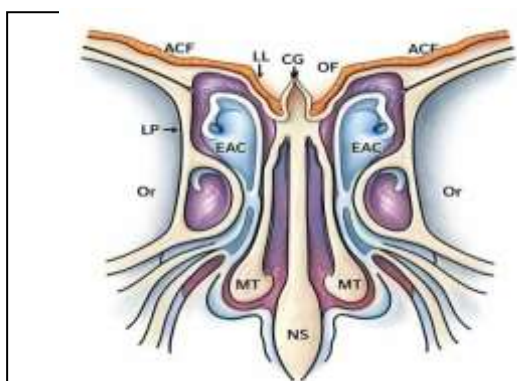


Fig 2: Photograph showing the anterior cranial fossa with the crista galli (CG) and cribriform plate (CP), highlighting the narrow anterior and wider posterior olfactory fossa (OF).



Fig 1:- Coronal diagram showing the olfactory fossa (OF) bounded by the lateral lamella (LL) and its relation to the nasal septum (NS) and crista galli (CG).

Objective

To evaluate anatomical variability of the olfactory fossa using Keros classification and associated morphometric parameters in an adult population.

Materials and Methods

Study population and study site

The research population comprised all patients who had paranasal sinus computed tomography at Index Medical College, Indore's Department of Radiodiagnosis.

Inclusion criteria

During the research period, non-contrast CT assessment of the paranasal sinuses was performed on all patients who were 18 years of age or older.

Exclusion criteria

Patients having a history of paranasal sinus injuries or fractures, those under the age of eighteen, and those with malignant tumors of the paranasal sinuses were all excluded from the research. The research excluded those who had previously had sinonasal surgery, as well as those who had congenital craniofacial anomalies or bone destructive diseases.

Study design

The study was a retrospective record-based observational study.

Sample size and sampling method

The study comprised all 140 patient records that met the inclusion and exclusion criteria that visited the department between June 2025 and December 2025.

Ethical considerations

The study was approved by the Institutional Ethics Committee of Index Medical College, Indore.

Data collection tools and radiological evaluation

The records that were accessible were used to extract demographic data. Using the coronal CT data, a single radiologist determined the olfactory fossa's depth. By measuring the vertical height of the lateral lamella of the cribriform plate—which is the difference between the level of the cribriform plate and the ethmoid roof—the olfactory fossa depth was determined from the coronal sections at the point of greatest depth. A 128-slice configuration scanner was used to perform computed tomography while the patient was in the supine position.

Statistical Analysis

SPSS software was used for statistical analysis. The data was summarized using descriptive statistics, such as mean, standard deviation, minimum, maximum, frequency, and percentage. The Kolmogorov-Smirnov test was used to determine if the distribution of quantitative data was normal. Besides that Mann-Whitney U test was used to examine differences in olfactory fossa depth between the right and left sides. In order to assess the distribution pattern among the study population, the Keros categorization was reported as frequencies and percentages. Statistical significance was defined as a p-value of less than 0.05.

Results

Table 1. Demographic Characteristics of the Study Population

Variable	Frequency (n)	Percentage (%)
Male	82	58.6
Female	58	41.4
Total	140	100

There were 140 participants in all, with 82 (58.6%) being men and 58 (41.4%) being women. As a result, the sample showed a moderate male preponderance. This distribution suggests that male participants made up over half of the research population, which might have an impact on gender-based comparison studies. Nonetheless, sufficient representation of both sexes allowed for a relevant statistical analysis of sex-related variations in Keros categorization and olfactory fossa depth.

Table 2. Descriptive Statistics of Olfactory Fossa Depth (mm)

Parameter	Right Side (n=140)	Left Side (n=140)
Mean	5.41	5.53
Standard Deviation	1.46	1.52
Minimum	2.0	2.1
Maximum	9.4	9.8

The average depth of the olfactory fossa was 5.53 ± 1.52 mm on the left side and 5.41 ± 1.46 mm on the right. The mean depth was somewhat greater on the left than the right. There was significant anatomical diversity on both sides, with the minimum and highest values ranging from 2.0 mm to 9.4 mm on the right and from 2.1 mm to 9.8 mm on the left. Similar bilateral variability is shown by the comparable standard deviations. The results show significant inter-individual heterogeneity and a modest left-sided predominance in mean depth.

Table 3. Overall Distribution of Keros Classification (n = 280 sides)

Keros Type	Frequency (n)	Percentage (%)
Type I (1–3 mm)	60	21.4
Type II (4–7 mm)	190	67.9
Type III (8–16 mm)	30	10.7
Total	280	100

Keros type II (4–7 mm) was the most prevalent kind, accounting for 190 (67.9%) of the 280 evaluated sides. While Keros Type I (1–3 mm) was identified in 60 sides (21.4%), Keros Type III (8–16 mm), the deepest and most medically vulnerable variety, was found in 30 sides (10.7%). These findings indicated that most people had moderate olfactory fossa depth (Type II), but a smaller but clinically relevant portion had deeper cribriform plate architecture (Type III), which may increase the risk of iatrogenic damage during endoscopic sinus surgery.

Table 4. Gender-wise Distribution of Keros Classification (Side-Based Analysis)

Keros Type	Male (n=164 sides)	Male (%)	Female (n=116 sides)	Female (%)	p-value
Type I	32	19.5	28	24.1	0.584
Type II	114	69.5	76	65.5	
Type III	18	11.0	12	10.4	
Total	164	100	116	100	

Gender-wise analysis showed that Type II was most prevalent (69.5%) among male sides (n = 164), followed by Type I (19.5%) and Type III (11.0%). In a similar vein, Type II predominated (65.5%) among female sides (n = 116), followed by Type I (24.1%) and Type III (10.4%). The distribution pattern was similar for both sexes, despite Type I being somewhat more common in females and Type II being significantly more common in males. There is no statistically significant correlation between gender and Keros categorization, according to the p-value of 0.584. Therefore, the distribution of olfactory fossa depth categories in the current study did not seem to be significantly influenced by gender.

Table 5. Difference in mean depth according to gender and side

Gender	Parameter	n	Mean	Standard Deviation	p-value
Male	Right side	82	4.95	1.40	>0.05
Female	Right side	58	4.72	1.35	
Male	Left side	82	5.05	1.50	<0.05
Female	Left side	58	4.70	1.38	
Total	Right side	140	4.85	1.37	>0.05
Total	Left side	140	4.92	1.44	

The olfactory fossa depth on the left and right sides, as well as the total side-based distribution, are compared between males and females in Table 5. Males showed somewhat more depth than females on the right side, but the difference was not statistically significant ($p > 0.05$). This suggests that the right-sided olfactory fossa depth in the current investigation is not significantly influenced by gender. On the other hand, a statistically significant difference between males and females was found on the left side ($p < 0.05$), indicating a considerable gender-based variation on this side, with males exhibiting comparatively larger depth. Overall bilateral symmetry in olfactory fossa depth was shown by the lack of a statistically significant difference between the right and left sides when both sides were examined collectively ($p > 0.05$).

Discussion

In the age of Functional Endoscopic Sinus Surgery (FESS), a comprehensive knowledge of the anatomy of the anterior skull base has become essential. Because they directly affect the likelihood of iatrogenic cerebrospinal fluid (CSF) leak and cerebral damage, variations in the olfactory fossa's

(OF) depth and Keros classification are particularly important from a surgical perspective.^[9] The olfactory fossa's mean depth in the current research was 5.41 ± 1.46 mm on the right side and 5.53 ± 1.52 mm on the left, with an overall mean of around 5.47 mm (0.55 cm). These results indicate relative consistency among populations and are similar to those published by Lang (0.50 cm) and Meloni et al. (0.59 cm).^[10-11] Erdem et al. reported an average depth of 0.61 cm, although our mean results are somewhat lower. Ethnic differences, radiographic vs anatomical technique, and different levels of ethmoidal and frontal sinus pneumatization might all be responsible for these variances between research.^[12] The total side-to-side difference was not statistically significant, despite the left side showing a slightly higher mean depth than the right. Numerous earlier CT-based investigations have similarly documented this bilateral symmetry. Minor asymmetries may be explained anatomically by differences in the degree of pneumatization of the frontal sinus and ethmoid labyrinth.^[13] These variations did not, however, attain statistical significance in our investigation, indicating that the group under research had comparatively symmetrical cranial base morphology. Type II (4–7 mm) was the most common design (67.9%) using Keros categorization, followed by Type I (21.4%) and Type III (10.7%). This distribution closely resembles Keros' initial findings, which indicated that Type II was the predominant pattern (~70%).^[14] Our study's Type III incidence (10.7%) is higher than that seen in several South Indian and Southeast Asian communities, but it is lower than that reported by Erdem et al. and Basak et al.^[15-16] These results imply that although the majority of olfactory fossae in our population are moderately deep, a clinically significant percentage (about one-tenth of sides) exhibit deep Type III structure, which is associated with a greater surgical risk. Fundamentally gender-wise analysis showed that there was no statistically significant correlation ($p = 0.584$) between sex and Keros type. Males had somewhat greater mean depths than females, although only on the left side was this difference statistically significant. The lack of a consistent gender-based difference implies that the distribution of olfactory fossa depth may not be significantly influenced by sex. Subtle structural differences, however, could exist and call for more research using bigger multicentric datasets. The need for careful preoperative radiological evaluation is highlighted by the Type III configuration found in 10.7% of sides. The thinnest and most fragile part of the front skull base is known to be the lateral lamella of the cribriform plate. A longer and thinner lateral lamella is correlated with increased depth, making it more vulnerable to surgical penetration. Preoperative diagnosis of deep olfactory fossae is crucial since a large percentage of CSF leaks are iatrogenic in origin. The occurrence of Type III instances and the modest predominance of deeper depth on the left side indicate that surgeons should be especially cautious while instrumenting the ethmoid roof. To identify unique anatomical variances and reduce surgical problems, coronal CT image examination is still crucial. The results support the idea that, with a minor prevalence of Type III, Keros Type II is the most prevalent anatomical type in the population under study. The noted anatomical differences emphasize how crucial a customized radiological evaluation is before endoscopic sinus surgery. To develop normative data and investigate any ethnic and regional differences in anterior skull base shape, more extensive, population-based research would be beneficial.

Conclusion

An objective and systematic approach to evaluating the anatomical diversity of the front skull base is the Keros classification. Keros Type II was the most prevalent configuration in the current investigation, followed by Type I and Type III, suggesting that the adult population under study had a preponderance of intermediate olfactory fossa depth. Type III was less common, but its existence indicates anatomical diversity that is clinically significant. The bilateral symmetry in olfactory fossa depth was also shown in the study, and there was no discernible correlation between gender and Keros classification. The overall distribution pattern was not significantly changed by the minor side- and gender-based variations that were noted. Accurate tracking of olfactory fossa morphology and improved comprehension of population-specific anatomical variations are made possible by routine, side-based evaluation of Keros categorization on coronal CT imaging. For anatomical and

radiological reference of the front skull base, this methodical evaluation provides useful morphometric data.

References:

- Perakis N, Belser UC, Magne P. Final impressions: a review of material properties and description of a current technique. *Int J Periodontics Restorative Dent*. 2004;24(2):109–17.
- Souza SA, Souza M, Idagawa M. Computed tomography assessment of ethmoid roof: a relevant region at risk in endoscopic sinus surgery. *Radiol Bras*. 2008;41:143-e147.
- Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. *Z Laryngol Rhinol Otol*. 1962;41:809–13.
- Costa ALF, Paixão AK, Gonçalves BC, Ogawa CM, Martinelli T, Maeda FA, et al. Cone beam computed tomography-based anatomical assessment of the olfactory Fossa. *Int J Dent [Internet]*. 2019;2019:4134260. Available from: <http://dx.doi.org/10.1155/2019/4134260>
- Pawar A, Konde S, Bhole P. Assessment of depth of olfactory fossa in pre-functional endoscopic sinus surgery computed tomography scan of paranasal sinuses. *Int J Otorhinolaryngol Head Neck Surg [Internet]*. 2017;4(1):83. Available from: <http://dx.doi.org/10.18203/issn.2454-5929.ijohns20174663>
- Güler C, Uysal İÖ, Polat K, Salk I, Müderris T, Koşar MI. Analysis of ethmoid roof and skull base with coronal section paranasal sinus computed tomography. *J Craniofac Surg [Internet]*. 2012;23(5):1460–4. Available from: <http://dx.doi.org/10.1097/SCS.0b013e31825755b2>
- Salroo IN, Dar NH, Yousuf A, Lone KS. Computerised tomographic profile of ethmoid roof on basis of keros classification among ethnic Kashmiri's. *Int J Otorhinolaryngol Head Neck Surg [Internet]*. 2016;2(1):1. Available from: <http://dx.doi.org/10.18203/issn.2454-5929.ijohns20151134>
- Kaplanoglu H, Kaplanoglu V, Dilli A, Toprak U, Hekimoğlu B. An analysis of the anatomic variations of the paranasal sinuses and ethmoid roof using computed tomography. *Eurasian J Med [Internet]*. 2013;45(2):115–25. Available from: <http://dx.doi.org/10.5152/eajm.2013.23>
- Savvateeva DM, Güldner C, Murthum T, Bien S, Teymoortash A, Werner JA, et al. Digital volume tomography (DVT) measurements of the olfactory cleft and olfactory fossa. *Acta Otolaryngol [Internet]*. 2010;130(3):398–404. Available from: <http://dx.doi.org/10.3109/00016480903283741>
- Lang J. *Klinische Anatomie der Nase, Nasenhohle und Nebenhöhlen*. Thieme Stuttgart. 1998:23-e27.
- Meloni F, Mini R, Rovasio S, Stomeo F, Teatini GP. Anatomic variations of surgical importance in ethmoid labyrinth and sphenoid sinus. A study of radiological anatomy. *Surg Radiol Anat [Internet]*. 1992;14(1):65–70. Available from: <http://dx.doi.org/10.1007/bf01628046>
- Hoang JK, Eastwood JD, Tebbitt CL, Glastonbury CM. Multiplanar sinus CT: a systematic approach to imaging before functional endoscopic sinus surgery. *AJR Am J Roentgenol [Internet]*. 2010;194(6):W527-36. Available from: <http://dx.doi.org/10.2214/AJR.09.3584>
- Şahan MH, Inal M, Muluk NB, Şimşek G. Cribriform plate, Crista Galli, olfactory Fossa and Septal Deviation. *Curr Med Imaging Rev [Internet]*. 2019;15(3):319–25. Available from: <http://dx.doi.org/10.2174/1573405614666180314150237>
- Almushayti ZA, Almutairi AN, Almushayti MA, Alzeadi HS, Alfadhel EA, Alsamani AN, et al. Alfadhel Sr EA. Evaluation of the Keros classification of olfactory fossa by CT scan in Qassim region. *Cureus*. 2022;14(2).
- Erdem G, Erdem T, Miman MC. A radiological anatomy of the cribriform plate compared with constant structures. *Rhinology*. 2004;42:225-e229.
- Başak S, Karaman CZ, Akdilli A, Mutlu C, Odabaşı O, Erpek G. Evaluation of some important anatomical variations and dangerous areas of the paranasal sinuses by CT for safer endonasal surgery. *Rhinology*. 1998;36(4):162–7.