A Study of Clinical Significance of the Depth of Olfactory Fossa in Patients Undergoing Endoscopic Sinus Surgery

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Abstract The endoscope has revolutionized the diagnosis and treatment of diseases of the nose and paranasal sinuses. Endoscopic sinus surgery (ESS), like all minimally invasive surgery, is designed to combine an excellent outcome with minimal patient discomfort. Successful outcome with minimal complications can only be achieved with good knowledge of the endoscopic anatomy, appropriate training in the procedure and the understanding of the anatomical variations. The intraoperative complications of ESS are bleeding and injury to surrounding structures commonly the orbital structures and fovea ethmoidalis. This is a hospital based prospective observational study with an objective to define the distribution of Keros classification of the depth of olfactory fossa and its asymmetrical distribution rates based on Keros type. Prospective study in a tertiary rural based hospital. 100 patients above the age of 10 years from October 2013 to March 2015 for a period of one year six months undergoing endoscopic sinus surgery in the Department of ENT, P.E.S. Institute of Medical Sciences and Research, Kuppam were chosen randomly. The data was collected from these patients who will met the inclusion criteria of the study and before undergoing endoscopic sinus surgery by subjecting them to CT scan of paranasal sinuses. It is observed that a total of 100 patients had been studied in which the mean age of the population is 36.65 ± 13.36 years. Youngest patient was 12 years old and eldest patient was 70 years old. Among the patients 50(50%) were males

and remaining 50(50%) were females with a female to male ratio is 1:1. In the present study, the depth of olfactory fossa ranged from 2.1 to 8.3 mm inclusive of both sides in 200 CT images with a mean height of 5.21 mm. Of the 200 sides measured, the distribution of Keros classification is as the following—Keros type I 39(19.5%), Keros type II 143(71.5%) and Keros type III 18(9%) sides. Based on these observations, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population. In the present study, on considering sides separately, the right side olfactory fossa depth ranged from 2.1 to 8.3 mm with a mean height of 5.43 mm and the left side olfactory fossa depth ranged from 2.1 to 8.1 mm with a mean height of 4.98 mm. On the right side, of 100 sides measured, the distribution of Keros classification is as the following—Keros type I 19(19%), Keros type II 68(68%) and Keros type III 13(13%) sides. On the left side, of 100 sides measured, the distribution of Keros classification is as the following—Keros type I 25(25%), Keros type II 70(70%) and Keros type III 5(5%) sides. Based on these observations, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population on both sides. In the present study, out of 100 patients 23 patients were having asymmetric olfactory fossa between right and left sides based on Keros type, where as remaining 77% had symmetric Keros type on right and left sides. Out of 23 patients, 16 patients were having lower or deep olfactory fossa on right side, where as remaining 7 patients were having lower or deep olfactory fossa on left side. Based on these observations, a lower or deep ethmoid roof occurred more frequently on the right side than on the left side. Wilcoxon matched

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pair signed rank test is applied to see the significant difference between depth of right and left olfactory fossae. Since P value is < 0.001 the depth of olfactory fossa is significantly different from each other. The present study presents a precise, quantitative analysis of the olfactory fossa and ethmoid roof position as well as individual asymmetry. This information may be useful during pre-operative evaluation of CT images, as well as intraoperatively. The surgeon's understanding of the anatomy of a patient's ethmoid roof and its possible variations is crucial for countering possible complication risks during endoscopic sinus surgery.

Keywords Keros classification · Olfactory fossa · Endoscopic sinus surgery · CSF leak · CT PNS

Introduction

Endoscopic sinus surgery (ESS) is a common operation which is not only indicated for the management of chronic rhinosinusitis that resists medical treatment, but it extends to include a number of conditions and approaches like: nasal polyposis, mucocele, sellar and parasellar tumours, and optic nerve decompression and other intracranial lesions [1]. Although ESS is widely performed, it is not devoid of complications. These can be divided into minor and major complications. Minor complications occur in 1.1–20.8% of functional endoscopic sinus surgery cases [2].

They include bleeding, infection, crusting, synechiae formation, ostial stenosis, tooth or lip numbness, and recurrence of the disease [2]. Major complications occur in 0–1.5% of such operations. They include, cerebrospinal fluid leak, ocular injury (herniation of orbital fat, extra-ocular muscle injury, ocular motility dysfunction, optic nerve injury, and peri-orbital hematoma or periorbital emphysema), and intracranial injury (brain or major blood vessels injury) [2, 3]. Most of the major complications are related to the ethmoid bone.

Aims and Objectives

1. The objective of the study was to describe the distribution of Keros classification among patients undergoing endoscopic sinus surgery.
2. To determine the depth of olfactory fossa and asymmetrical distribution rates of the Olfactory fossa based on Keros type between right and left sides in patients undergoing endoscopic sinus surgery.

Methodology

Study Population

100 patients of both the genders above 10 years of age who are undergoing endoscopic sinus surgery in the Department of E.N.T, P.E.S. Institute of Medical Sciences and Research, Kuppam.

Study Design Hospital based prospective observational study.

Sampling Method Simple random sampling.

Study Period One year six months. From October 2013 to March 2015.

Inclusion Criteria

1. All patients undergoing endoscopic sinus surgery.
2. Patients of both the genders.
3. Patients of age group above 10 years.
4. Patients consenting to be included under the study.
5. Patients not having any other major medical illness.
6. Patients consenting to take CT scan of PNS.

Exclusion Criteria

1. Patients below the age group of 10 years.
2. Previous history of surgery or trauma in the paranasal sinuses or skull base,
3. Congenital abnormalities of the face,
4. Malignant disease of nose and paranasal sinuses,
5. Cerebrospinal fluid leak.
6. PATIENTS with other associated comorbidities/major medical illness.
7. Patients not fit for radiation exposure.

Sample Size

100 patients who are undergoing endoscopic sinus surgery in the Department of E.N.T, P.E.S. Institute of Medical Sciences and Research, Kuppam.

Study instrument GE—Bright speed, 16 slice, multidetector CT scan.

Data Collection

The data was collected from those patients who will met the inclusion criteria of the study and before undergoing endoscopic sinus surgery by subjecting them to CT scan of paranasal sinuses.

Protocol

Patient position Supine.

Region Roof of frontal sinuses to inferior wall of maxillary sinus.

Scanogram Lateral and AP.

Plane of imaging Axial-parallel to hard palate and coronal and sagittal reconstruction.

Mode Spiral.

Scan Orientation Caudo-cranial.

Slice Thickness 2.5 mm contiguous.

Pitch 1–1.5 mm.

Reconstruction 5 mm.

Field of View 200 mm.

KVp and mAS 130 KVp and 90 mAS.

Window Settings Bone (width/centre: 2000/400).

Statistical Analysis

The data obtained was documented using Microsoft word and excel and evaluated using the descriptive statistical methods (mean, standard deviation, median, frequency, percentiles).

The Wilcoxon matched pair signed rank test is applied to see the significant difference between depth of right and left fossa.

The results were evaluated in a 95% validity range, and $p < 0.05$ was considered significant.

Observations and Results

For the study of distribution of Keros classification of the depth of olfactory fossa and its asymmetrical distribution rates based on Keros type, 100 patients undergoing endoscopic sinus surgery in the department of ENT, P.E.S. Institute of Medical Sciences and Research, Kuppam were chosen randomly.

Observations are tabulated in Table 1.

In this study, it is observed that a total of 100 patients had been studied in which the mean age of the population is 36.65 ± 13.36 (Table 2).

Youngest patient was 12 years old and eldest patient was 70 years old.

Among the patients 50% were males and remaining 50% were females. The female to male ratio is 1:1 (Table 3).

In this study, it is observed that a total of 100 patients had been studied in which the mean age of the population is 36.65 ± 13.36 . Youngest patient was 12 years old and eldest patient was 70 years old (Table 4).

In a total of 100, 50 male patients had been studied in which the mean age of the population is 33.50 ± 12.88 .

Table 1 Age distribution of patients ($n = 100$)

Sl. no.	Age group (years)	Number of cases	Percentage %
1	11–20	10	10
2	21–30	30	30
3	31–40	28	28
4	41–50	16	16
5	51–60	11	11
6	61–70	05	05
7	71–80	0	0.0
	Total	100	100
	Mean $\pm$ SD	36.65 ± 13.36	

Table 2 Gender distribution of patients ($n = 100$)

Sl. no.	Sex	Number of cases	Percentages %
1	Male	50	50
2	Female	50	50
	Total	100	100

Table 3 Age and gender distributions ($n = 100$)

Sl. no.	Age group (years)	Males	%	Females	%	Total	%
1	11–20	5	5	5	5	10	10
2	21–30	23	23	7	7	30	30
3	31–40	10	10	18	18	28	28
4	41–50	5	5	11	11	16	16
5	51–60	5	5	6	6	11	11
6	61–70	2	2	3	3	5	5
7	71–80	0	0.0	0	0.0	0	0.0
	Total	50	50	50	50	100	100
	Mean $\pm$ SD	33.50 ± 12.88		39.80 ± 13.20		36.65 ± 13.36	

Table 4 Distribution of Keros classification in total patients of 200 sides ($n = 200$)

Sl. no.	Keros classification	Frequency	Percentage %
1	I	39	19.5
2	II	143	71.5
3	III	18	9.5
	Total	200	100

Youngest patient was 12 years old and eldest patient was 67 years old.

In a total 100, 50 female patients had been studied in which the mean age of the population is 39.80 ± 13.20 .

Youngest patient was 13 years old and eldest patient was 70 years old.

In this study, the depth of olfactory fossa ranged from 2.1 to 8.3 mm inclusive of both sides in 200 CT images with a mean height of 5.21 mm. Of 200 sides measured, the distribution of Keros classification is as the following

Keros type I (0–3.99 mm)—39(19.5%)
Keros type II (4–6.99 mm)—143(71.5%)
Keros type III (7–16 mm)—18(9%).

Based on these observations, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population.

In this study, on considering sides separately, the right side olfactory fossa depth ranged from 2.1 to 8.3 mm with a mean height of 5.43 mm and the left side olfactory fossa depth ranged from 2.1 to 8.1 mm with a mean height of 4.98 mm.

On the right side, of 100 sides measured, the distribution of Keros classification is as the following

Keros Type I (0–3.99 mm)—19(9.5%)
Keros Type II (4–6.99 mm)—68(34%)
Keros Type III (7–16 mm)—13(6.5%).

On the left side, of 100 sides measured, the distribution of Keros classification is as the following

Keros Type I (0–3.99 mm)—25(12.5%)
Keros Type II (4–6.99 mm)—70(35%)
Keros Type III (7–16 mm)—5(2.5%).

Based on these observations, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population on both sides.

In this study, out of 100 patients 23 patients were having asymmetric olfactory fossa between right and left sides based on Keros type, whereas remaining 77% had symmetric Keros type on right and left sides.

Out of 23 patients, 16 patients were having lower or deep olfactory fossa on right side, where as remaining 7 patients were having lower or deep olfactory fossa on left side.

Based on these observations, a lower or deep ethmoid roof occurred more frequently on the right side than on the left side.

Discussion

Computed tomographic (CT) scan of nose and paranasal sinus plays a key role in pre-operative evaluation of patients undergoing endoscopic sinus surgery. The

asymmetries of ethmoidal fovea, olfactory fossa, anatomical variations of lateral lamella are critical in ESS as it may predispose to dangerous consequences like hemorrhage, CSF leak and intracranial complications.

Mosher [4] in 1912 stated that intranasal ethmoidectomy is “the blindest and most dangerous surgery”. Over the years the incidence of complications has reduced due to improved surgical experience, knowledge of the endoscopic anatomy and better equipment and instruments.

Computed tomography has contributed greatly to the diagnosis and evaluation of sinonasal diseases, and also to the characterisation of important anatomical landmarks. This fact has been documented in several studies [5, 6] highlighting the relevance and precision of radiographic evaluation of the ethmoid roof, and its validity for the provision of safe ‘roadmaps’ for surgeons.

In a series of over 4000 cases, Stammberger and Wolf [7] reported only two cases of CSF rhinorrhoea, no intracranial complications and no ophthalmic problems. Wigand [8] reporting on 220 patients undergoing complete ethmoidectomy mainly for polypoid, reported a CSF leak in two (0.9%) and one case of an orbital haematoma (0.5%).

Stankiewicz [9] suggested that the complication rate decreases with increasing experience, reporting a rate of 29% in the first 90 cases which he performed compared with only 2.2% in the subsequent 90. Most of the cases were minor, such as adhesions, but there were two cases of CSF rhinorrhoea and one case of temporary blindness. ‘Conventional’ surgery is not immune from these problems and Maniglia [10] reported seven cases of blindness, four cases of CSF rhinorrhoea and two deaths following intranasal ethmoidectomy, while a 2.8% complication rate was reported for this operation by Freedman and Kern [11].

In a group of 650 consecutive patients [12], one patient developed a CSF leak on the third postoperative day, after he sneezed. This was managed endoscopically with a free mucoperichondrial graft from the opposite side of the septum. One further case required an external ethmoidectomy at the time of the surgery, due to an orbital haematoma resulting from bleeding from the anterior ethmoidal artery which retracted into the orbit. Both cases underwent satisfactory and uneventful postoperative recovery. There have been no cases of diplopia, blindness, meningitis or death.

In a survey of British otolaryngologists [13], a questionnaire sent to 653 members of the British Association of Otolaryngologists, received a 57 percent response, of whom 38% were reportedly routinely undertaking functional endoscopic sinus surgery. The estimated complication rate was 0.24%, predominantly CSF leaks, followed by problems related to bleeding. All occurred in patients with diffuse polypoid.

A recent audit undertaken by the Clinical Effectiveness Unit of the Royal College of Surgeons of England considered 3128 patients with chronic rhinosinusitis/nasal polyposis in whom the majority underwent endoscopic sinus surgery. Of these, 0.2% developed periorbital haematoma, but there were no long-term visual problems [14].

A working party of The Royal College of Surgeons of Edinburgh [15] was set up to consider ways of reducing complications associated with endoscopic sinus surgery.

Among the various conclusions it included the following suggestions.

The operator should have experience of at least a 100 diagnostic endoscopic procedures before attempting surgery.

The surgeon should attend and participate in a course or workshop that allows hands-on experience.

Where possible a proctor system should be encouraged with an experienced surgeon attending initial operations.

Follow-up and assessment clinics should, wherever possible, be separate from the general clinics and should be used for training and audit purposes.

CT scan facilities should be available.

Although some of these recommendations have been subsumed in normal training programmes, the underlying tenets remain.

Concerns have been raised regarding the long-term effects of such surgery, for example as to whether surgery in the frontal recess might lead to frontoethmoidal mucocoele formation in the future and in particular the effects of endoscopic surgery on facial growth in children. This has not been supported by longitudinal clinical studies [16] and indeed disruption of facial growth is unlikely given that major sinus procedures such as external ethmoidectomy, lateral rhinotomy, midfacialdegloving and craniofacial resection appear to have no detrimental effect in the long term [17].

Computed tomography (CT) has contributed not only to the evaluation of sinonasal diseases, but also to the characterization of the paranasal sinuses anatomy. Coronal images can particularly be considered as maps in the evaluation of the anatomy that is highly variable even between the two sides of a same individual, demonstrating areas potentially at risk for complications in the planning of endoscopic nasal surgeries. The reasoning for the choice of this theme is associated with the evaluation of anatomical findings that may determine a higher intraoperative safety during surgeries in the frontoethmoidal region, giving the surgeon previous knowledge about the configuration of the ethmoidal roof and depth of olfactory fossae, consequently reducing the patient exposure to potential complications.

In 1962, Keros [18] classified the depth of the olfactory fossa into Keros type I (< 3 mm), type II (4–7 mm) and type III (8–16 mm). Depending on the Keros type, a

variable segment of the lateral wall of the olfactory fossa will be exposed during the dissection of the frontoethmoidal region. The Keros type III is the most vulnerable one, considering the major risk for iatrogenic lesion of the lateral lamella of the cribriform plate.

The Keros type III is considered as the most vulnerable for iatrogenic lesion during frontoethmoidal surgery due to its long length of the lateral lamella [6, 19–21]. The area of the entry of AEA through the lateral lamella into the olfactory fossa is considered the thinnest and at risk of injury causing CSF leak [5, 6, 21]. Damage to the AEA can lead to profuse haemorrhage with the formation of orbital hematoma due to retraction of the lacerated artery into the orbit.

The endoscope brings better vision and exposure with lesser bleeding—together leading to better results. An optimal preoperative evaluation including CT scan and a thorough knowledge of paranasal anatomy is paramount in a successful endoscopic sinus surgery. These asymmetries in the anatomy of ethmoidal roof need to be kept in mind to prevent complications.

For the present study of distribution of Keros classification of the depth of olfactory fossa and its asymmetrical distribution rates based on Keros type between right and left sides, 100 patients undergoing endoscopic sinus surgery in the department of ENT, P.E.S. Institute of Medical Sciences and Research, Kuppam were chosen randomly.

Variables that are taken and compared with the present study includes the following.

1. Age distribution of patients
2. Gender distributions
3. Age and gender distributions
4. Distribution of Keros classification in total patients of 200 sides
5. Distribution of Keros classification between right and left sides based on Keros type
6. Asymmetrical distribution rates of olfactory fossae based on Keros type between right and left sides
7. Statistics of significance of comparison of right and left sides based on olfactory fossa measurements.

In a similar study conducted by Nair [22]. The CT scans from 180 patients were analysed. Of these cases, the mean age of the population is 32.2 years. Youngest patient was 16 years old and eldest patient was 62 years old. Of 180 patients studied, according to Keros classification, the depth of olfactory fossa complies with Keros type I in 31(17.2%) sides, Keros type II in 139(77.2%) sides, and Keros type III in 10(5.6%) patients. Present study is comparable with these results.

In a similar study conducted by Souza et al. [23]. The CT scans from 200 patients were analysed. Of these cases, 117(58.5%) were female patients and 83 (41.5%) were

male patients. Of 400 sides measured, According to Keros classification, the depth of olfactory fossa complies with Keros type I in 105(26.2%) sides, Keros type II in 293(73.3%) sides, and Keros type III in 2(0.5%) sides. Present study is comparable with these results.

In a similar study conducted by Ali et al. [24]. Out of 75 patients studied, the olfactory fossa was type I in 15 patients (20%), type II in 59 patients (78.7%) patients and type III in 1 patient (1.3%). Present study is comparable with these results.

In a study conducted by Bista et al. [25]. The CT scans of 50 patients were analysed. Of these cases, 22(44%) were female patients and 28(56%) were male patients. Out of 100 sides measured, the median height of the lateral lamella cribriform plate (LLCP) was 2.8 mm, according to Keros classification, the LLCPC height complies with Keros type I in 86(86%) sides, Keros type II in 12(12%) sides, and Keros type III in 2(2%) sides. The results of this study are not in favour of the results of the present study.

As mentioned in Table 5, in the present study, on considering sides separately, the right side olfactory fossa depth ranged from 2.1 to 8.3 mm with a mean height of 5.43 mm and the left side olfactory fossa depth ranged from 2.1 to 8.1 mm with a mean height of 4.98 mm.

On the right side, of 100 sides measured, the distribution of Keros classification is as the following

Keros Type I (0–3.99 mm)—19(19%)

Keros Type II (4–6.99 mm)—68(68%)

Keros Type III (7–16 mm)—13(13%)

which was consistent with the study done by Kaplanoglu et al. [26], Souza et al. [23] and others.

On the left side, of 100 sides measured, the distribution of Keros classification is as the following

Keros Type I (0–3.99 mm)—25(25%)

Keros Type II (4–6.99 mm)—70(70%)

Keros Type III (7–16 mm)—5(5%)

which was consistent with the study done by Kaplanoglu et al. [26], Souza et al. [23] and others.

Based on these observations, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population on both sides which was consistent with the

study done by Kaplanoglu et al. [26], Souza et al. [23] and others.

In a study conducted by Kaplanoglu et al. [26]. The CT scans of the 500 cases were analysed. Of these cases, 261(52.2%) were female patients with a mean age of 38.90 and 239(47.8%) were male patients with a mean age of 39.94. The average height of the lateral lamella cribriform plate (LLCP) was 4.92 ± 1.70 mm, and the median was 4.90 and the height of the lateral lamella cribriform plate (LLCP) ranged from 0.9 to 10.5 mm.

On considering sides separately, the right side mean olfactory fossa depth was 4.87 ± 1.71 mm and on the left side mean olfactory fossa depth was 4.91 ± 1.66 mm.

On the right side, of 500 sides measured, according to Keros classification, the depth of olfactory fossa complies with Keros type I in 68(13.6%) sides, Keros type II in 381(76.2%) sides, and Keros type III in 51(10.2%) sides.

On the left side, of 500 sides measured, according to Keros classification, the depth of olfactory fossa complies with Keros type I in 66(13.2%) sides, Keros type II in 380(76%) sides, and Keros type III in 54(10.8%) sides. The results of this study is consistent with the present study.

In a similar study conducted by Souza et al. [23]. The CT scans from 200 patients were analysed. Of these cases, 117(58.5%) were female patients and 83 (41.5%) were male patients.

On the right side, of 200 sides measured, according to Keros classification, the depth of olfactory fossa complies with Keros type I in 53(26.5%) sides, Keros type II in 146(73%) sides, and Keros type III in 1(0.5%) sides.

On the left side, of 200 sides measured, according to Keros classification, the depth of olfactory fossa complies with Keros type I in 52(26%) sides, Keros type II in 147(73.5%) sides, and Keros type III in 1(0.5%) sides. The results of this study is consistent with the present study.

Asymmetrical Distribution Rates of Olfactory Fossae Based on Keros Type Between Right and Left Sides

As mentioned in Table 6, in the present study, out of 100 patients 23 patients were having asymmetric olfactory

Table 5 Distribution of Keros classification between right and left sides of total patients based on Keros type ($n = 100$)

Sl. no.	Keros classification on right side	Frequency	Percentage %	Keros classification on left side	Frequency	Percentage %
1	I	19	9.5	I	25	12.5
2	II	68	34	II	70	35
3	III	13	6.5	III	5	2.5
	Total	100	50	Total	100	50

Table 6 Asymmetrical distribution rates of olfactory fossae based on Keros type between right and left sides ($n = 100$)

Sl. no.	Type of olfactory fossa between right and left sides based on keros type	Frequency	Percentage %
1	Symmetric	77	77
2	Asymmetric	23	23
	Total	100	100

fossa between right and left sides based on Keros type, where as remaining 77% had symmetric Keros type on right and left sides which was consistent with the study done by Nair [22], Lebowitz et al. [27], Ali et al. [24] and others.

Out of 23 patients, 16 patients were having lower or deep olfactory fossa on right side, where as remaining 7 patients were having lower or deep olfactory fossa on left side which was consistent with the study done by Nair [22], Lebowitz et al. [27], Ali et al. [24] and others.

Based on these observations, a lower or deep ethmoid roof occurred more frequently on the right side than on the left side which was consistent with the study done by Nair [22] and Ali et al. [24].

In a similar study conducted by Nair [22]. The CT scans from 180 patients were analysed. Of these cases, The mean age of the population is 32.2 years. Youngest patient was 16 years old and eldest patient was 62 years old. Out of the 180 patients analysed 21(11.7%) patients had asymmetry of height. Of the 21 patients with asymmetry of height, 15(71.4%) showed low fovea on right side and 06(28.6%) patients on the left side. The results of this study is consistent with the present study.

In their retrospective study with 200 cases, Lebowitz et al. [27] found asymmetric ethmoid roof heights in 19 cases. They found that the right side ethmoid roof height was lower in 12(63.2%) cases and that the left side ethmoid roof height was lower in 7(36.6%) of the cases in which asymmetry was determined. In their study using 150 Italian patients, Dessi et al. [28] found ethmoid roof height asymmetry in 15(10%) cases. They found a lower average right ethmoid roof height than left ethmoid roof height in 13 of the cases with asymmetry.

Possible Explanation for Variations in the Results

These studies support and strengthen the hypothesis that the ethmoid roof configuration varies between population. The differences between the results of this study and the other studies conducted may be due to the use of different measurement techniques. The cross section in which the infra-orbital nerve follows the base of the orbit was taken as the reference point for the measurements in this study.

Literature has reported that this reference point is more relevant during surgery, can be identified after endoscopic maxillary antrostomy, and can assist in informing the surgeons of the position of the ethmoid roof, especially for cases in which endoscopic maxillary sinus antrostomy is performed [29].

This result may be because our study was conducted using a smaller sample and because measurements were performed digitally. This difference may suggest, for instance, hormonal factors in the development of the craniofacial asymmetry.

This significant difference in the result between the current study and Keros's study may be attributed to the difference in populations, and varied techniques of measurement (CT scan analysis vs cadaveric dissection) and variation in grouping the measurements into different types as the original Keros classification ignored the measurements between 0–1, 3–4 and 7–8 mm. The present study included these measurements and grouped them into different types as Keros type I (0–3.99 mm), Keros type II (4–6.99 mm), Keros type III (7–16 mm) respectively.

This significant difference in the result between the current study and other studies may be attributed to the difference in populations of different ethnicity and of races.

Significant variations are also observed between males and females which has not been taken into account in the present study.

High rate of asymmetry noted in our population comparing to other studies [27, 28]. This is mostly due to the accurate measurement using the computer software, which is able to measure the height with a precision of 0.1 mm.

Statistics of significance of comparison of right and left sides based on olfactory fossa measurements

As mentioned in Table 7, Wilcoxon matched pair signed rank test is applied to see the significant difference between depth of right and left olfactory fossae.

Table 7 Statistics of significance of comparison of right and left sides based on olfactory fossa measurements

Data description	Right fossa	Left fossa
<i>N</i>		
Valid	100	100
Missing	0	0
Percentiles		
LQR	4.2500	4.0000
Median	6.0000	5.0000
UQR	6.0000	6.0000

LQR Lower quartile range, *UQR* Upper quartile range

Wilcoxon matched pair signed rank test is applied to see the significant difference between the depth of right and left fossa

Since P value is < 0.001 the depth of olfactory fossa is significantly different from each other

Since P value is < 0.001 the depth of olfactory fossa is significantly different from each other.

This result is consistent with the study done by Kaplanoglu et al. [26] and Arikan et al. [30].

The significance of these results includes that an injury of the base of the skull with cerebrospinal fluid leaks occur more frequently when an endonasal sinus surgery is being performed on the right side [28, 31, 32].

Furthermore, the type of handedness can play a special role in surgery, particularly in the training phase [33]. We found no systematic studies in the literature which examined the role of handedness in this area. However, we think that not the handedness is so important but rather which side of the patient the surgeon is standing during surgery. Performing surgery on the left side of the paranasal sinuses is easier for the surgeon than performing it on the right side, if he/she is standing on the right side of the patient. It is better to start the surgery on the more difficult right side, when the surgeon is more focused and attentive [28, 31, 34]. The fact that in 8–26% of the cases, the ethmoid roof is lower on the right side than on the left side might furthermore explain why the incidence of the respective complication is higher on the right side.

In addition, a possible lower or flattened and particularly dehiscent ethmoid roof on the right side is another reason to prepare for surgery on the right side with special care. The possibility of intracranial penetration on the side with a very low fovea during endonasal sinus surgery is much higher. The asymmetry of the height and should always be taken into account preoperatively by careful review of the CT scans of the paranasal sinuses.

Conclusions

1. The importance of the Keros classification lies primarily in the avoidance of iatrogenic injury to the cribriform region and medial ethmoid roof.
2. In present study, type II is the most common Keros type prevalent followed by type I Keros type and the least prevalent is the type III Keros type in the studied population.
3. A lower or deep ethmoid roof occurred more frequently on the right side than on the left side
4. The height of the ESB can vary substantially and should be assessed during preoperative evaluation of the sinus CT. Utilization of an objective preoperative CT measurement technique may improve identification and optimize surgical awareness of this potentially dangerous anatomic skull base variation.
5. A meticulous pre-operative assessment of CT scan by the surgeon is mandatory to avoid serious iatrogenic complications in this endoscopic era.

6. Greater depths are constantly associated with greater risk of intracranial penetration when performing endoscopic surgery, so the ENT surgeon must know the kind of relationship between the cribriform region and medial ethmoid roof.
7. This study highlights the importance of careful preoperative and intraoperative review of paranasal sinus CT scans in patients undergoing ESS to prevent complications.

Compliance with Ethical Standards

Conflict of interest The authors have no conflict of interests, financial or otherwise.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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