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Analysing the Frontal Sinus Outflow Pathway: A Radiological and Anatomical Study

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ABSTRACT

The obscure location of the frontal sinus, anatomical variations, complexities and its proximity to delicate structures creates a problem during dissection and obstructs clear visualization. Hence, a clear understanding of the anatomy and drainage pathway of the frontal sinus is essential for successful surgical outcome. Analysis of samples to measure and study the drainage of the frontal sinus with respect to uncinate process, study of aggarnasi cells as present or absent and relevant linear and angular measurements to facilitate easy approach to the frontal sinus. Forty CT scans were analysed using the latest version of RadiAnt DICOM viewer in sagittal view. Twelve cadaveric skulls were dissected and measurements taken with a probe, protractor and scale. The radiographs showed pneumatizedaggarnasi cells in 88.75% of plates. The drainage pattern was anterior to the uncinate process in all plates. The sinus ostium diameter and angles measured were similar among sexes and on both sides. However, the distance from the frontal beak to columella and to nasal spine was statistically less in females. The cadaveric study resulted in slightly different values compared to radiographs especially regarding the ostium diameter and angle with nasal floor. The other values were comparable to similar studies. A large portion of literature regarding the anatomy of the frontal sinus are cadaveric studies. Studies collecting superior radiological data with uniform parameters should be conducted. Considering the variations in the available data, a meta-analysis will help settle the problem.

INTRODUCTION

The anatomy of outflow pathways involved in the drainage of the frontal sinus has gained importance in the years following the advent of Functional Endoscopic Sinus Surgery (FESS)[1]. FESS has wide applicationin the definitive management of pathologies including chronic rhinosinusitis, polyposis, mucocele, fungal diseases, foreign body removal and trauma repair[2]. FESS includes visualising the lateral wall of nose and removing the uncinate process to expose the hiatus semilunaris, this is where the frontal sinus ostium lies[2]. Opening of the ostia leads to better visualisation, ventilation and drainage of the maxillary, ethmoid and frontal sinuses which is an essential part of the definitive management[2]. However, the complexity of this anatomical region poses surgical challenges leading to a demand for detailed anatomical knowledge with respect to common landmarks of the region[1-4]. Frontal sinus dissection and visualisation is difficultdue the crowding and compact arrangement of structures in this area and is a major cause of post procedural complications[5,3,6,7].

The outflow pathway of the frontal sinus is in the shape of an hourglass the ostium forming the narrowest part and the sinus and the frontal recess(FR) making up the upper and lower portions respectively[5] (fig. 3). A significant factor affecting outflow is the frontal recess of the osteo-meatal complex[8]. Variable pneumatization and variations in air cells and size of this recess, directly impacts the patency of the sinus[1], hence the primary target of FESS is the frontal recess . The important boundaries of the FR are the agger nasi cells anteriorly, the ethmoid bulla posteriorly and the uncinate process above and lateral to it[1,9].The anterior portion of the ostium is named as "frontal beak"[10].

Variations in these structures affect the drainage and are thus predisposing factors to diseases of the frontal sinus[8,11,12,13]. Ethnicity and gender also influences the anatomy of the region[11]. Cadaveric studies involving various parameters have been conducted in the past using sinus probing, image guided mapping etc but studies conducted using techniques such as CT multiplanar reconstruction are far superior[14,15]. Hence, CT scans are now an essential tool and mandatory prior to FESS to shed light of patient specific variations[16,2]. Despite the fact, most of the data we have has been acquired from cadaveric studies. Therefore, the present study was undertaken to study the gross anatomy of the nasofrontal region by cadaveric dissection as well as CT scans performed in a tertiary health care centre in India.

Aims and objectives: The study aims to perform measurements of various parameters belonging to the frontal sinus outflow pathway using both radiological data of CT scans and anatomical specimens, to identify variations in the frontal sinus outflow pathway that will be important from a surgical perspective and in turn improve the outcome of FESS.

Parameters: Cadaveric dissection and CT PNS (paranasal sinus) analysis of frontal sinus and its drainage tract will be performed to identify and measure the following parameters:

- To identify and locate the position of frontal sinus ostium
- Anterior to the uncinate process
- Posterior to the uncinate process
- Hypoplastic frontal sinus

Study of agger nasi cells as under:
- Present or absent

Linear and angular measurements to facilitate easy approach to the frontal sinusas under (fig. 5):

- Diameter of the frontal ostium is measured as the distance between the frontal beak and the posterior rim of the frontal ostium
- Angle formed by the plane of the frontal ostium to the floor of the nose
- Distance of the frontal beak to the anterior nasal spine
- Angle of the frontal beak to the nasal floor with the anterior nasal spine as a reference point
- Distance of the frontal beak to the base of the columella
- Angle of the frontal beak to the nasal floor with the columella as a reference point

The above data will be analysed to detect variations between the right and left sides and between sexes.

MATERIALS AND METHODS

The study was conducted in a tertiary health centre and teaching hospital in Western Maharashtra. Ethical clearance from institutional ethical committee was taken. Fourty CT PNS scans were obtained with permissions from the hospital records of the Radiology Department (26 males and 14 females). The scans of patients less than 16yrs and patients with gross distortion of anatomy such as that due to trauma were excluded.

Right and left halves of 12elderly appearing male cadavers embalmed at the Department of Anatomy were dissected after taking sagittal section. Thus, both sides of sagittal sections were dissected from each cadaver. The lateral wall of nose was dissected using scalpel and blunt forceps. A metallic probe was used to locate the ostium. Fine tipped colour pencils were used for measurement. Other instruments used for various measurements are divider, protractor and a scale giving a least count of 1 degree and 1 mm respectively. The dissection was done as per Cunningham's Manual of Practical Anatomy, Volume III[17]. The nasal septum and middle turbinate were removed from each of the specimen. The drainage of the frontal sinus identified and followed to its opening in the nose by passing the probe through the base of the frontal sinus (Fig. 1). After exposing the frontal ostium at frontal beak, diameter of the ostium and angle formed by the plane of the frontal ostium to the floor of the is measured. The bony lamina of frontal recess was broken down to detect agger nasi cells. The site for drainage of agar nasi cells was confirmed by passing the probe through its opening. The bony landmarks were identified and the measurements taken.

The CT scans were analysed using the latest version of RadiAnt DICOM viewer. Plates were seen in sagittal view with multiplanar reconstruction. The dimensions were calculated using in-built measuring tools.Readings were taken from the radiographs in sagittal view as seen in Fig. 2: A,B, C and D.

Data analysis: Readings were tabulated Mean and standard deviation were calculated. The unpaired T-test was used to compare values from right and left side and to compare between males and females.

RESULTS

Radiographic study: Out of 40 plates i.e., 80 sides the radiographs showed pneumatized agger nasi cells in 88.75%of plates. The drainage pattern was anterior to the uncinate process in all plates. Tables 1 and 2 show the data obtained from the radiological study. The sinus ostium and angles measured were similar among sexes and on both sides. However, the distance from the frontal beak to columella and to nasal spine was statistically less in females. (Unpaired T-test $p<0.0001$)

Results cadaveric study: Out of 24 sagittal sections studied, 8.3% had a hypoplastic frontal sinus. The findings for the remaining 22 specimens are given in Table 3. Agger nasi pneumatization was observed in 31.81% of samples. All the specimens drained anterior to the uncinate process. Findings from the right and left sides was compared and the difference was not statistically different. Since all were male cadavers, gender wise comparison was not possible.

DISCUSSIONS

Studies undertaking the task of measuring the frontal sinus outflow pathway previously relied on cadaveric data. However, considering the minute size of these structures and the soft tissue deformity in embalmed cadavers, this appears to be a crude method and has now been replaced by radiological studies to get exact measurements. Irrespective of the

Fig. 1: Metallic probe inserted through frontal sinus enters through ostium into hiatus semilunaris

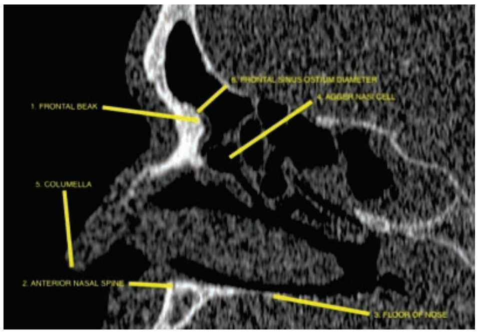

Fig. 2: A: Bony Landmarks: 1. Frontal beak, 2. Anterior nasal spine, and 3. Floor of nose. 4. Agger nasi cell 5. Columella 6. Frontal sinus ostium diameter

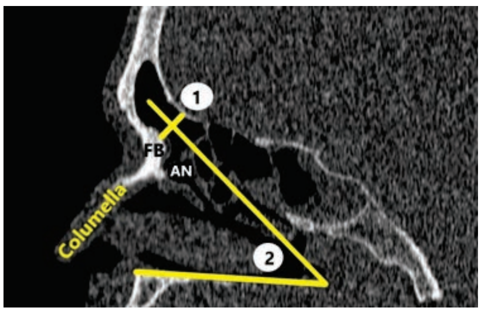

Fig. 3: B: Columella, diameter of frontal sinus (1), frontal beak (FB), Agger nasi cells (AN), angle made by plane of the sinus with the floor of nose (2)

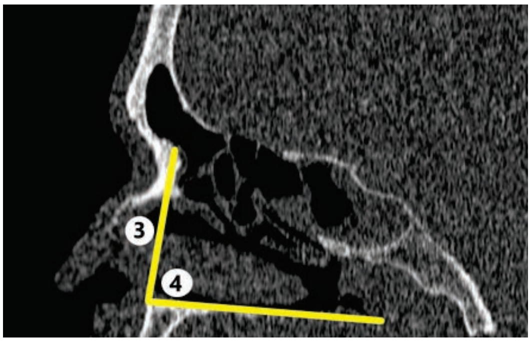

Fig. 4: C: Distance between the frontal beak and the anterior nasal spine (3) and angle made by the frontal beak with the floor of nose at the anterior nasal spine (4)

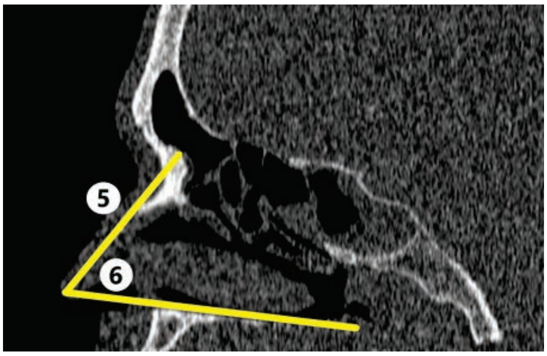

Fig. 5: D: Distance between the frontal beak and the columella (5) and angle made by the frontal beak with the floor of nose at the columella (6)

modality, to measure anatomical details, it is necessary to define landmarks. The studies conducted till date, do not show uniformity in the landmarks used to measure them. The parameters utilized in this study are justified and discussed herewith[19]. Bony prominences considered include the frontal beak and the nasal spine. The significance of the frontal beak lies in that it forms the anterior wall of the frontal sinus opening, this wall is vital to locating the frontal sinus[10]. The uncinate process is to be removed prior to access to the sinus because it can obscure the sinus opening[2]. The nasal spine is surgically important as it is a midline structure and is the entry point for FESS. Moreover, itis related to the floor of nose which in turn is easily visualised by the surgeon. The drawback with bony landmarks is that they are not directly visualised by the operating surgeon but are visualised in radiological scans taken prior to surgery. Therefore, an orientation of the soft tissue seen by surgeons while performing FESS, for example, the columella is also necessary[20]. Hence, our measurements include distances from the frontal beak to the nasal spineand columella and angles it forms with the nasal floor respectively. The ostium diameter was measured. The frontal sinus completes development by 21 years, hence the age of the patients is not likely to affect the results of our study.

Table 4 and 5 showthe values obtained by similarradiological and cadavericstudies respectively. Due to variability in parameters used, only the measurements relevant to this study are included. The parameters of our study closely resembled those of Gaffer *et al*.[21] and Gupta *et al*.[22] There was no statistical difference between sides and genders which was in agreement with our study. Some studies described the measurements to be larger in males.

The percentage of pneumatization in radiological study found by various authorslike Talaiepour *et al*.[28] was 56.7%, Tiwari and Goyal[29] was 7% . Zinreich *et al*.[30] was 98.5%, Mendiratta *et al*.[8] was 80% , Johari *et al*.[31] was was 98.15, Choby *et al*.[32] was 96.5%, Yüksel Aslier et al.[33] was 64.2%, Dearking *et al*.[34] was 92%, Zhang *et al*.[35] was 90.5%, Bradley *et al*.[36] 93%, Delglaudio *et al*.[37] was 86.7%, Bolger *et al*.38] was 98.5%, Lloyd *et al*.[39] was 20% while that of current study by Radiological analysis was 88.75%. Similarly, the pneumatization of agger nasi in cadaveric studies done by Davis *et al*.[40] was 65%, Van *et al*.[41] was 89%, Dhingra *et al*.[42] was 20%, Angélico *et al*.[1] was98.7%, Thanaviratananich et al.[26] was 100% while that of Current study was 31.81%.

The cadaveric study revealed lesser pneumatization. The cause of this could be that the cadavers may show post-mortem changes and CT scans obtained were those of living patients. Agger nasi cells are known to increase chances of obstruction to sinus drainage and hence will be more commonly seen in patients who are subjected to CT scan which is the source of data in our study.

The drainage pattern in the present study was predominantly anterior to the uncinate process which differed from previous studies. The studies with percentage of sample showing sinus drainage anterior to uncinate process were Kim *et al*.[43] (cadaveric) 59%, Lee et al.[44] (cadaveric) 29.3%, Kasper *et al*.[45] (Cadaveric) 57%, Gaffar *et al*.[23] (cadaveric) 23.3%, Tulika *et al*.[25] (cadaveric) 59.4%, Gnanavelraja *et al*.[46] (cadaveric) 70% and in Current study of Cadaveric method, it was 100% means almost all sections had sinus drainage anterior to uncinate process.

There are also differences between the cadaveric and radiological data of current study. This further emphasises that cadaveric dissection is a crude method and CT PNS should be used as the method of choice for reliable measurements of these parameters. There is evidently a wide variation in the values observed invarious studies. Although some of these may be attributed to racial variations it is important to combine this with the findings of other studies in the form of a meta-analysis.

Table 1: Data from radiological study: Side wise Comparison

	1. ostium diameter (mm)		2. angle of ostium to nasal floor		3. FB to nasal spine (mm) floor at nasal spine		4. angle of FB with		5. FB to columella (mm) to floor at columella		6. angle of FB	
Number of values	Male (25)	Female (14)	Male	female	Male	female	Male	female	Male	female	Male	female
Minimum	3.000	5.500	24.00	24.00	42.00	34.00	59.00	66.00	52.00	45.00	39.00	45.00
Maximum	13.50	10.20	55.00	67.00	56.00	52.00	92.00	97.00	66.00	58.00	57.00	59.00
Mean	8.266	7.779	40.00	39.54	49.72	45.71	73.62	74.54	57.78	51.82	50.02	51.29
Std. Deviation	1.990	1.423	6.779	8.058	3.201	3.670	6.651	6.653	3.430	3.244	3.310	3.332

Table 2: Data from radiological study: Gender wise comparison

	ostium diameter (mm)		angle of plane of ostium to nasal floor		FB to nasal spine (mm)		angle of FB with nasal at nasal spine floor		FB to columella (mm)		angle of FB to nasal floor at columella	
Number of values (39)	Rt	Lt	Rt	Lt		Rt	Lt	Rt	Lt	Rt	Lt	Rt Lt
Minimum	4.500	3.000	30.00	24.00	34.00	37.00	59.00	59.00	46.00	45.00	39.00	43.00
Maximum	12.10	13.50	55.00	67.00	56.00	56.00	92.00	97.00	64.00	66.00	57.00	59.00
Mean	7.941	8.241	40.03	39.64	48.18	48.38	73.74	74.15	55.67	55.62	50.38	50.56
Std. Deviation	1.730	1.903	6.360	8.061	3.999	3.788	6.680	6.647	4.157	4.705	3.431	3.315

Table 3: Data from cadaveric study: Sidewise comparison

Parameter	1. ostium diameter (mm)		2. angle of ostium to nasal floor (degrees)		3. FB to nasal spine (mm)		4. angle of FB with floor at nasal spine (degrees)		5. FB to columella (mm)		6. angle of FB to floor at columella (degrees)	
	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt
Number of values	11	11	11	11	11	11	11	11	11	11	11	11
Minimum	1	2	59	56	37	37	48	40	41	46	42	34
Maximum	4	5	83	100	53	55	88	78	58	59	70	62
Mean	2.818	3.182	74.18	75.27	44.27	46.73	72.91	66.55	50.45	51.91	55.73	52.82
Std. Deviation	0.9816	1.168	7.534	13.98	5.12	4.777	10.41	11.23	4.865	4.784	8.486	8.268

Table 4: Comparison of results with other radiological studies

Author	Frontal Ostium Diameter (mm)	Frontal Ostium Angle (degree)	Frontal beak to anterior nasal spine Distance (mm)	Frontal beak to anterior nasal spine Angle (degree)	Frontal beak to columella Distance (mm)	Frontal beak to columella Angle (degree)
Jacobs et al. (Radiological)[27]	10.4					
Angélico FV Jr et al. (Radiological)[1]	8.18 (Right) 8.08(Left)					
Eloy JA et al. (Radiological)[20]			52.3±3.4mm in men and 47.7±3.5mm in women		58.9±2.3mm in men and 53.0±3.3mm in women	
Current Radiological Study (R- Right, L- Left)	R-7.94 L-8.24	R-40.03 L-39.64	R-48.18 L-48.38	R-73.74 L-74.15	R-55.67 L-55.62	R-50.38 L-50.56

Table 5: Comparison of results with other cadaveric studies

Author	Frontal Ostium Diameter (mm)	Frontal Ostium Angle (degree)	Frontal beak to anterior nasal spine Distance (mm)	Frontal beak to anterior nasal spine Angle (degree)	Frontal beak to columella Distance (mm)	Frontal beak to columella Angle
Gaffar *et al*. (Cadaveric)[23]	5.6	22	50.6	69	57.2	55
Yang *et al*. (Cadaveric)[24]	8.5	60.8	70			
Tulika Gupta *et al*. (Cadaveric)[25]	4.6	26	46.5	70	48.7	57
Thanaviratananich *et al*.(Cadaveric)[26]	6.5					
Present study						
Cadveric	3	74.73	45.5	69.73	51.18	54.27

Limitations: The differences obtained between the cadavers and CT scans could be due to the fact that the CT scans were obtained from patients who had indication for CT scan of PNS. On the other hand, the history of such indication in cadavers is unknown. However, this does not reduce the validity of our findings as the prior group are the patients who would likely present to the ENT specialist and hence, their data is clinically relevant. The degree of pneumatization is less in cadavers. This may be due to two factors. Firstly, as agger nasi pneumatization can lead to outflow obstruction so it is more likely to be seen in patients who have an indication for CT of PNS. Secondly, identification of pneumatization is more difficult in cadavers leading to underestimation.

CONCLUSION

A large portion of literature regarding the anatomy of the frontal sinus are cadaveric studies. The current study measured the relevant linear and angular measurements to facilitate an easy approach to the frontal sinus during endoscopic sinus surgery, using both cadaveric and radiological data. There is a wide variation in the datapreviously available which could be attributed to racial differences. The cadaveric data did not match the values obtained from the radiological study. To find out an answer to this, Authors plan to conduct similar study using similar parametersof radiological data obtained from patients undergoing CT of Head Neck and Face regionand not having any indication for CT-PNS. The meta-analysis might give an answer to the variations observed in the previously conducted and present study.

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REFERANCES

1. Junior, F.V.A. and P.B. Rapoport, 2013. Analysis of the agger nasi cell and frontal sinus ostium sizes using computed tomography of the paranasal sinuses. Braz. J. Otorhinolaryngol., 79: 285-292.
2. Weber, R.,K.W. and Hosemann, 2015. Comprehensive review on endonasal endoscopic sinus surgery. GMS. Curr. Top. Otorhinolaryngol. Head. Neck. Surg., Vol. 14.

3. Vázquez, A., S. Baredes, M. Setzen and J.A. Eloy, 2016. Overview of frontal sinus pathology and management. Otolaryngologic Clin. North Am., 49: 899-910.
4. Wormald, P., W. Hoseman, C. Callejas, R.K. Weber and D.W. Kennedy, 2016. The international frontal sinus anatomy classification (ifac) and classification of the extent of endoscopic frontal sinus surgery (efss). Int. Forum. Allergy. Rhinology., 6: 677-696.
5. Lessa, M.M., R.L. Voegels, B.C. Filho, F. Sakae, O. Butugan and G. Wolf, 2007. Frontal recess anatomy study by endoscopic dissection in cadavers. Braz. J. Otorhinolaryngol., 73: 204-209.
6. Stammberger, H.,R.D.W. and Kennedy, 1995. Paranasal sinuses:anatomic terminology and nomenclature. Ann. Otol. Rhinol. Laryngol. Suppl., 167: 7-16.
7. Friedman, M., R. Landsberg, R.A. Schults, H. Tanyeri and D.D. Caldarelli, 2000. Frontal sinus surgery: Endoscopic technique and preliminary results. Am. J. Rhinology., 14: 393-404.
8. Mendiratta, V., N. Baisakhiya, D. Singh, G. Datta, A. Mittal and P. Mendiratta, 2015. Sinonasal anatomical variants: Ct and endoscopy study and its correlation with extent of disease. Indian J. Otolaryngology. Head. Neck. Surg., 68: 352-358.
9. McLaughlin, R.B., R.M. Rehl and D.C. Lanza, 2001. Clinically relevant frontal sinus anatomy and physiology. Otolaryngol. Clin. North Am., 34: 1-22.
10. Craig, J.R., D. Petrov, S. Khalili, S.G. Brooks, J.Y.K. Lee, N.D. Adappa and J.N. Palmer, 2016. The nasofrontal beak: A consistent landmark for superior septectomy during draf iii drill out. Am. J. Rhinology. Allergy., 30: 230-234.
11. House, L.K., S.P. Stringer and S. Seals, 2017. Correlation of frontal sinus recess anatomy with ethnicity, gender, and pathology. Am. J. Otolaryngology., 38: 452-455.
12. Turgut, S., I. Ercan, I. Sayin and M. Basak, 2005. The relationship between frontal sinusitis and localization of the frontal sinus outflow tract. Arch. Otolaryngology. Head. Neck. Surg., 131: 518-518.
13. Lien, C., H. Weng, Y. Chang, Y. Lin and W. Wang, 2010. Computed tomographic analysis of frontal recess anatomy and its effect on the development of frontal sinusitis. Laryngoscope., 120: 2521-2527.
14. Kewm J.,G.L. Rees. and D. Close, 2002. Multiplanar reconstructed computed tomography images improves depiction and understanding of the anatomy of the frontal sinus and recess. Am. J. Rhinol., 16: 119-123.
15. Ansari, K., H. Seikaly and G. Elford, 2003. Assessment of the accuracy and safety of the different methods used in mapping the frontal sinus. J. Otolaryngology., 32: 254-258.
16. Papadopoulou, A.M., D. Chrysikos, A. Samolis, G. Tsakotos and T. Troupis, 2021. Anatomical variations of the nasal cavities and paranasal sinuses: A systematic review. Cureus., 13: 12727-12727.
17. Cunningham., 1986. Cunningham's Manual of Practical Anatomy. 15th Edition, Volume 3, Pg 149. Oxford Medical Publication. 15th Ed. Edn., Cunningham., Oxford. Medical. Publication., Pages: 149.
18. Korban, Z.R. and R.R. Casiano, 2016. Standard endoscopic approaches in frontal sinus surgery. Otolaryngologic Clin. North Am., 49: 989-1006.
19. Baudoin, T., T. Greguric, F. Bacan, B. Jelavic, G. Geber and A. Košec, 2021. A systematic review of common landmarks in navigated endoscopic sinus surgery (ness). Comput. Assisted Surg., 26: 77-84.
20. Eloy, J.A., D.M. Neskey, R.J. Vivero, J.W. Ruiz, O.J. Choudhry and R.R. Casiano, 2013. High-resolution computed tomography analysis of the frontal sinus ostium: A pilot study. Am. J. Otolaryngology, 34: 99-102.
21. Tatlisumak, E., G.Y. Ovali, M. Asirdizer, A. Aslan, B. Ozyurt, P. Bayindir and S. Tarhan, 2008. Ct study on morphometry of frontal sinus. Clin. Anat., 21: 287-293.
22. Pondé, J.M., P. Metzger, G. Amaral, M. Machado and M. Prandini, 2003. Anatomic variations of the frontal sinus. min. Minimally. Invasive. Neurosurg., 46: 29-32.
23. Gaafar, H., M.H. Abdel-Monem, 2001. Frontal sinus outflow tract "anatomic study. Acta. Otolaryngol. (Stockh)., 121: 305-309.
24. Yang, Q.,T.J.B. Shi. and Z. Kang, 2004. Computer-assisted anatomical study of nasofrontal region. Zhonghua., 39: 349-352.
25. Gupta, T.,A. Aggarwal. and D. Sahni, 2013. Surgical anatomy of the frontal sinus outflow pathway: A cadaveric study. Eur. J. Anat., 17: 29-34.
26. Thanaviratananich, S. and P Vatanasapt, 2012. Frontal sinus drainage in Thai adult skulls. J. Med. Assoc. Thail. Chotmaihet. Thangphaet., 95: 130-134.
27. Jacobs, J.B., R.A. Lebowitz, A. Sorin, S. Hariri and R. Holliday, 2000. Preoperative sagittal ct evaluation of the frontal recess. Am. J. Rhinology., 14: 33-38.
28. Talaiepour, A.,A. Sazgar. and A. Bagheri, 2022. Anatomic Variations of the Paranasal Sinuses on CT scan Images. undefined., Vol. 3.
29. Tiwari, R. and R. Goyal, 2014. Study of anatomical variations on ct in chronic sinusitis. Indian. J. Otolaryngology. Head. Neck. Surg., 67: 18-20.
30. Zinreich. and J., 1993. Imaging of inflammatory sinus disease. Otolaryngol. Clin. North. Am., 26: 535-547.

31. Johari, H.H., I. Mohamad, I.S. Sachlin, M.E. Aziz, T.Y. Mey and R.R. Ramli, 2018. A computed tomographic analysis of frontal recess cells in association with the development of frontal sinusitis. Auris. Nasus. Larynx, 45: 1183-1190.
32. Choby, G., A. Thamboo, T. Won, J. Kim, L.C. Shih and P.H. Hwang, 2018. Computed tomography analysis of frontal cell prevalence according to the international frontal sinus anatomy classification. Int. Forum. Allergy. Rhinology., 8: 825-830.
33. Aslier, N.G.Y., N. Karabay, G. Zeybek, P. Keskinoglu, A. Kiray, S. Sütay and M.C. Ecevit, 2017. Computed tomographic analysis. J. Craniofacial Surg., 28: 256-261.
34. Dearking, A.C. and J.F. Pallanch, 2012. Mapping the frontal sinus ostia using virtual endoscopy. Laryngoscope., 122: 2143-2147.
35. Zhang, L., Han, D. min, Ge. and W. tong, 2005. Anatomical and computed tomographic analysis of the interaction between uncinate process and agger nasi cells Zhonghua. Er. Bi. Yan. Hou. Tou. Jing. Wai. Ke. Za. Zhi., 40: 912-916.
36. Bradley, D.,T.S.E. and Kountakis, 2004. The role of agger nasi air cells in patients requiring revision endoscopic frontal sinus surgery. Head. Neck. Surg. Off. J. Am. Acad. Otolaryngol. Head. Neck. Surg., 131: 525-527.
37. DelGaudio, J.M., P.A. Hudgins, G. Venkatraman and A. Beningfield, 2005. Multiplanar computed tomographic analysis of frontal recess cells. Arch. Otolaryngology. Head. Neck Surg., 131: 230-230.
38. Bolger, W.E., D.S. Parsons and C.A. Butzin, 1991. Paranasal sinus bony anatomic variations and mucosal abnormalities: Ct analysis for endoscopic sinus surgery. Laryngoscope., 101: 56-64.
39. Toro, G., 2015. Locking plate fixation of distal femoral fractures is a challenging technique: A retrospective review. Clin. Cases. Mineral. Bone. Metab., 12: 55-58.
40. Malvia, S., S.A. Bagadi, U.S. Dubey and S. Saxena, 2017. Epidemiology of breast cancer in Indian women. Asia-Pac. J. Clin. Oncol., 13: 289-295.
41. Pascarella, R., C. Bettuzzi, G. Bosco, D. Leonetti, S. Dessì, P. Forte and L. Amendola, 2013. Results in treatment of distal femur fractures using polyaxial locking plate. Strategies. Trauma. Limb. Recon, 9: 13-18.
42. Agarwal, A., J. Passey and J. Kaul, 2009. Anatomical analysis of the frontal recess cells in endoscopic sinus surgery-an Indian perspective. An. Int. J. Clin. Rhinology., 2: 15-20.
43. Ramirez, P.T., M. Frumovitz, R. Pareja, A. Lopez and M. Vieira et al., 2018. Minimally invasive versus abdominal radical hysterectomy for cervical cancer. New Engl. J. Med., 379: 1895-1904.
44. Lee, D., R. Brody and G. Har-El, 1997. Frontal sinus outflow anatomy. Am. J. Rhinology., 11: 283-286.
45. KASPER, K.A., 1936. Nasofrontal connections: A study based on one hundred consecutive dissections. Arch. Otolaryngology. Head. Neck. Surg., 23: 322-343.
46. Gnanavelraja, C., S.D. Nalinakumari and M. Rajajeyakumar, 2019. Anatomical variation in the drainage pattern of frontal sinus a cadaveric study. Nat. J. Clin. Anat., 8: 117-120.