

INCIDENCE OF CONGENITAL APLASIA AND HYPOPLASIA OF FRONTAL PARANASAL AIR SINUS AMONGEST THE POPULATION OF WESTERN UP REGION

Dr. Vipin Kaul, Dr. Nisha Kaul, Dr. Poonam Dutt, Sangeeta Chauhan

1. Post graduate student (Periodontics & Oral implantology), Shree Bankey Bihari Dental College & Research centre, Delhi-Hapur road, Masuri, Ghaziabad, Uttar Pradesh
2. Professor of Anatomy, Santosh Medical College, Ghaziabad, Uttar Pradesh, India
3. Professor & HOD (Periodontics & Oral Implantology), Shree Bankey Bihari Dental College & Research Centre, Delhi-Hapur Road, Masuri, Ghaziabad, Uttar Pradesh
4. Research Associate, Department of Science and Technology, New Delhi

Submitted on: January 2017

Accepted on: January 2017

For Correspondence

Email ID:

nishakaul.nk@gmail.com

Abstract

Introduction: The frontal air sinuses are a pair of air containing hollow spaces situated within the frontal bone measuring 28 mm (L), 24mm (W), 20mm (AP) on an average as quoted by Grey's anatomy. The size and anatomic relations of the sinus depend upon the extent of pneumatization of the frontal bone. A considerable reduction or total absence of pneumatization results in hypoplasia/ aplasia of the frontal sinus.

Aim: To investigate the prevalence of aplasia/ hypoplasia of the frontal sinus in a population of western UP because the frontal sinus is very vulnerable during surgical procedures of the skull due to its close relationship with orbit and anterior skull base.

Material and Methods: The study was carried on randomly selected PA cephalograms of 150 adult humans, attending the radiology dept. of SMH GZB some private hospitals situated in Ghaziabad. The frontal sinuses on both sides were studied for their presence or absence in the x-ray.

Results: 44 out of 150 cases showed aplasia/ hypoplasia of frontal sinus on x-ray; with cases of only aplasia in 31.81% cases; only hypoplasia in 50% cases and cases of one side aplasia with other sided hypoplasia in 18.18% of cases.

Discussion: The entity “APLASIA OF FRONTAL PARANASAL AIR SINUS” has been found as early as 1943. It is found to be in a very high percentage in all Eskimos. Genetic factor and cold climate are said to be closely associated with this conditions besides primary congenital anomalies and secondary pathological conditions. Variations in the anatomy of frontal sinuses are critical 1. for neurosurgeons while performing pterional or supraorbital craniotomy to avoid risks of intraoperative & postoperative complications and improve success of post-operative management strategies 2. For morphological and forensic investigations.

Keywords: Frontal Sinus, Aplasia/Hypoplasia, Development, Prevalence, Intraoperative and Post-Operative Complications

Introduction:

The humans and apes have pneumatized bones in the facial skeleton and cranial vault in common with most primates. Since these pneumatized bones lie by the side of the nose & drain into the nasal cavity, hence they are called as paranasal sinuses.⁽¹⁾

Definition:

Paranasal sinuses are a group of four paired air-filled spaces in the bones of face that surround the nasal cavity. The sinuses are 1. the maxillary sinuses occupying the maxillary bone, 2. the frontal sinuses lying within the frontal bones, 3. The ethmoidal sinuses arranged in three groups in ethmoid bones and 4. The sphenoidal sinuses occupying the sphenoid bones are located behind the eyes.⁽²⁾

The biological role of paranasal sinuses:

a) Decreasing the relative weight of the front of the skull, and especially the bones of the face, b). increasing resonance of the voice, c). Providing a buffer against facial trauma, d). Insulating sensitive structures like dental roots and eyes from rapid temperature fluctuations in the nasal cavity⁽³⁾, e) insulation of the cerebrum and orbits, and participation in the formation of the cranium⁽⁴⁾, f) Humidifying and heating of inhaled air because of slow air turnover in this region, g) Regulation of intranasal and serum gas pressures, h). Immunological defense, i) Contribute to facial growth.

New findings of the role of paranasal sinuses:

A) Sleep Apnea and Its Relation With The Sinuses:

Humidification of inhaled air by sinuses contributes up to 6.9mm Hg serum pO₂. In any condition of nasal obstruction, breathing has to be by mouth. Mouth breathers are noted to have decreased end-tidal CO₂. This leads to an increased serum

CO₂ which in turn is responsible for apneas (high baseline)

B) Production of Nitric Oxide (NO) gas: It is produced primarily in sinuses.^(5,6)

It is toxic to bacteria, fungi, viruses, 2. It increases ciliary motility.⁽³⁾

Anatomy of frontal sinus:

The frontal sinuses are funnel shaped air spaces, two in number, situated in the posterior part of the superciliary arches, between the external and internal plates of the frontal bone. They are seldom symmetrical; generally, there is a septum between both sinuses, which usually deviates from the midline. They sinuses point upwards beyond the middle part of superciliary and backward to the medial part of the orbital roof. The sinuses are divided into several recesses, which communicate with each other through incomplete bony septa arising from above. Occasionally one or both sinuses may be absent. The degree of prominence of superciliary arches does not indicate the absence, presence or changed the size of the frontal sinus. The extension upwards beyond the frontal bone may be a small one, while the extension into the orbital part of frontal bone may be bigger.^(7,8)

The asymmetry in the configuration of frontal sinuses, as a rule, is because of unequal absorption of the diploe during the development of the sinus. The chances of two people having a similar pattern of frontal sinuses are very remote.^(9,10) The morphology of frontal sinus of even twins (monozygotic and dizygotic) is found to be always different.^(10,11)

Average dimensions:

Volume: 1.1 to 38mm or a capacity of 30-37 cc with a mean of 10 cc; AP diameter: 3.1 - 18mm; Transverse diameter: 4 - 96 mm; sagittal diameter: 11-75mm. The size of the sinus and its anatomic relationship also

depends upon the extent of pneumatization. The extent of pneumatization results in the individual size and shape of the frontal sinus. ^(7, 12, 13)

Male/female predominance.

The values of measurements and other parameters are greater in males as compared to females. ^(10, 14) and the presence of metopic suture is associated with the absence of the frontal sinus. ⁽¹⁴⁾ The prominence of superciliary arcs does not indicate the absence, presence or indication of the size of the frontal sinus. ⁽¹³⁾

Drainage of frontal sinus

The floor of the frontal sinus slopes inferiorly towards the midline. Close to the midline, the primary ostium is situated. ⁽¹⁰⁾ The drainage usually occurs directly into the frontal recess or into the frontal recess by way of rudimentary ethmoidal cells. ⁽¹³⁾ The recess opens directly into the middle meatus in 62% of the subjects and into the ethmoid infundibulum in 38%. ⁽¹⁵⁾

Development of frontal sinus

The frontal sinuses arise from one of the several outgrowths that originate in the region of the frontal recess of the nose, or from anterior ethmoidal cells of the ethmoid infundibulum as early as 3-4 months of intrauterine life, but do not develop. They are absent at birth but effectively appear to start only after the second year of. By the age of 4 years, the average cranial extent of the frontal sinus reaches half the height of the orbit and extends just above the top of the most anterior ethmoid cells. By the age of 8 years, the top of the frontal sinuses is at the level of the orbital roof, and by the age of 10 years, the sinus extends into the vertical portion of the frontal bone. The final

adult proportion is reached only after puberty. ⁽¹⁵⁾ Frontal sinus shows no changes after the age of 20 years and remains stable through life until old age when gradual pneumatization can occur from atrophic changes. ⁽¹⁶⁾

Comparative anatomy of frontal sinuses:

In common with most primates, humans, and apes have pneumatized bones in the facial skeleton and cranial. ⁽¹⁾ However, genetic and environmental (i.e. nutritional, hormonal, muscular) factors control the configuration of the frontal sinus within each population. ⁽¹⁰⁾

Anatomical variations of frontal sinus:

1. An unusual bilateral posterior extension of the frontal sinus mucosa into the orbital roof has been observed. ⁽¹⁷⁾
2. Paranasal sinus agenesis is an uncommon anomaly that appears mainly in the frontal sinus. ⁽⁴⁾
3. Hypoplasia - the smaller (underdeveloped) sinuses. ⁽¹⁸⁾

Aplasia of Frontal sinus

It is defined as the absence of frontal bone pneumatization with no ethmoid cells extending above a horizontal line tangential to the supraorbital margin. ^(13,15) Frontal sinus aplasia is also defined as an oval-shaped sinus with the lateral margin medial to a vertical line drawn through the middle of the orbit (vertical line) with a smooth superior margin and an absence of the sinus septa. This condition could arise because of failure of absorption of the diploe of frontal bone during the development of the sinus or failure of upward migration of anterior ethmoidal cells to penetrate the inferior aspect of the frontal bone between its outer and inner tables. ⁽¹³⁾

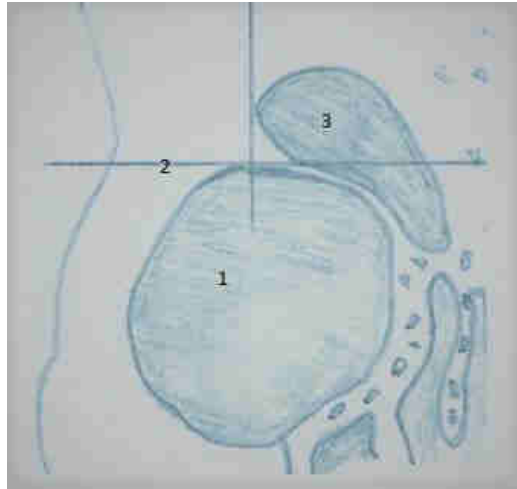


Fig 1: A schematic diagram depicting 1. orbit, 2. tangent to supraorbital margin, 3. aplastic/hypoplastic frontal sinus⁽¹³⁾

Hypoplasia of frontal sinus

A hypoplastic frontal sinus is an underdeveloped sinus cavity located in the center of the forehead.⁽¹⁹⁾

Hidden unilateral frontal sinus aplasia

It is the absence of one frontal sinus with increased pneumatization of contralateral sinus toward the aplastic side. It may give the false impression of the presence of two separate frontal sinuses, creating the potential for complications during the surgery.⁽²⁰⁾

Incidence:

The frequency of frontal sinus agenesis is variable between different ethnic populations. Occasionally, one or both sinuses may be absent.⁽¹³⁾

Different authors have given varied incidences as follows.

- *The frequency of bilateral absence of the frontal sinus has been reported in 3-4% to 10% of several populations.⁽²¹⁾
- *A bilateral and unilateral absence of the frontal sinuses in Turkish population was seen in 0.73% and 1.22% of cases, respectively.⁽¹³⁾
- * In comparison an earlier observation on frontal sinus in Turkish population is b/absence in 3.8% & unilateral absence 4.8 %.⁽²²⁾
- *The frequency has been seen significantly higher in some populations, including

Alaskan Eskimos (25% in males and 36% in female) and Canadian Eskimos (43% in males and 40% in female).^(23, 24)

- *Frontal sinus agenesis was reported bilaterally in about 4% of cases and bilaterally in approximately 5% of cases.⁽²⁵⁾
- *Frontal sinus aplasia is present unilaterally in 15% and bilaterally in 5% of normal adults of the population of USA as reported.⁽²⁶⁾
- *The usual incidence of frontal sinus aplasia is 5% in Egyptian population according to Haze Abu.⁽²⁷⁾
- *10 percent of all adults have hypoplastic frontal sinuses.⁽¹⁹⁾

Causes of aplasia /hypoplasia:

Aplasia /hypoplasia of frontal sinus can be congenital or secondary to some pathology. The size & configuration of frontal sinus, by and large, may be related to **environmental and genetic factors without any congenital or acquired pathologies**. The degree of pneumatization correlates positively with the degree of environmental coldness in which the population lives.

Three systemic factors influence the frontal sinus morphology.

1. Craniofacial configuration 2. The thickness of frontal bone 3. Growth hormone. ⁽²²⁾

Congenital causes:

1. Arrest of the development because of infection, injuries, and irradiation in utero.
2. Congenital first arch syndrome.
3. Developmental anomalies such as craniosynostosis, osteodysplasia, and Down syndrome. ⁽⁴⁾
4. During the fetal period, the FS and posterior ethmoidal cells are still rudimentary surrounded by cartilage. It is possible that earlier ossification of the cartilage will interfere with their further development, manifesting as a hypoplastic or aplastic sinus. ⁽⁸⁾

Acquired causes:

1. Trauma with deformity due to fracture or surgery in the sinus region.
2. Thalassemia and cretinism.
3. Wegener's granuloma (inflammatory osteitis)
4. Neoplasms that cause osteitis. ⁽⁴⁾

Presentation of frontal sinus aplasia/hypoplasia:

Cases of frontal sinus aplasia /hypoplasia right from birth:

The patient may be completely asymptomatic; the diagnosis of frontal sinus aplasia may be a chance discovery following x-ray PNS or CT scan paranasal sinus. ^(18, 28)

Some patients, however, may present with a headache, rhinorrhea, giddiness, feeling of heaviness in the forehead. In addition, patients with frontal sinus aplasia with chromosomal anomaly may present other correlating features. ⁽⁴⁾

General Symptoms: anxiety, depressed mood, insomnia, fatigue, and pain regardless of the condition are also observed. ⁽²⁹⁾

Cases of frontal sinus aplasia secondary to the pathological condition:

The patient will present primarily with different features related to the concerned pathological problem; the diagnosis of

frontal sinus aplasia comes following various investigations.

Aims and Objectives: The study to assess the prevalence of aplasia/hypoplasia of frontal sinus was undertaken to enable us for the following reasons:

1. Planning operative strategies for some craniofacial surgeries.
2. Understanding the etiopathogenesis of cases of sleep apnea and nasal congestion and nasal discharge of unknown origin.
3. Help in personal identification of living as well as the dead individual in forensic medicine.
4. Add to the knowledge of the anthropological study of human race.

Material and Method:

The research was conducted by studying the cephalograms of adult patients between the age group of 30-70 yrs. The x-rays were obtained from the patients, attending the radiology depts. of Santosh hospital Ghaziabad and some private hospitals situated in Ghaziabad.

Inclusion Criterion:

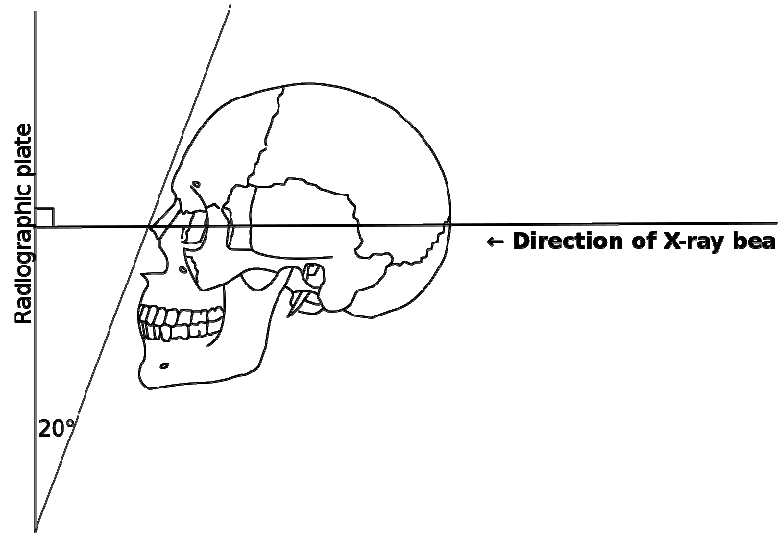
Cephalograms of only those patients were included for our observation who fulfilled the following criterion:

1. Were previously examined and evaluated with respect to the anatomic and physiologic integrity of the frontal sinus.
2. Had no h/o orthodontic treatment or orthognathic surgery.
3. Had no h/o trauma, or any surgery of the skull.
4. Had no history or clinical characteristics of endocrine disturbances, nutritional diseases or hereditary facial asymmetries.

Technique:

The radiographs were taken by Caldwell technique to view the frontal sinus utilizing Kodak radiographic film, size 8'x 10' inches. Radiography was performed with a PLANMECA apparatus with a distance of 3 m from source to film, using an exposure of 80 KVP and time of 2 sec at 10 mA. X-rays

were then studied on view box to see the presence of frontal sinus, absence (aplasia) of sinus or presence of a very small frontal sinus (hypoplasia).⁽³⁰⁾



Caldwell's radiographic view of skull

Fig 2: Caldwell's view (or Occipitofrontal view) is a radiographic view of the skull, where X-ray plate is angled at 20° to the orbitonasal line. The rays pass from behind the head and are perpendicular to the radiographic plate. It is commonly used to get a better view of frontal sinuses.⁽³¹⁾

RESULTS:

As shown in tabular form

TOTAL NO. OF CASES= 150

NO. OF POSITIVE CASES= 44 (29.33%)

CASES OF APLASIA = 14 (31.81%)

CASES OF HYPOPLASIA = 22 (50%)

CASES OF ONE SIDED APLASIA AND OTHER SIDED HYPOPLASIA = 8 (18.18%)

Table 1. Showing cases of Aplasia (Fig a, Fig b, Fig c)

S. No.	Particulars	Numbers	Percentage
1.	No. of cases with aplasia	14	31.81%
1.1	Bilateral aplasia	7	50%
1.2	Right sided aplasia	6	42.85%
1.3	Left sided aplasia	1	7.14%



Fig a: Bilateral Aplasia

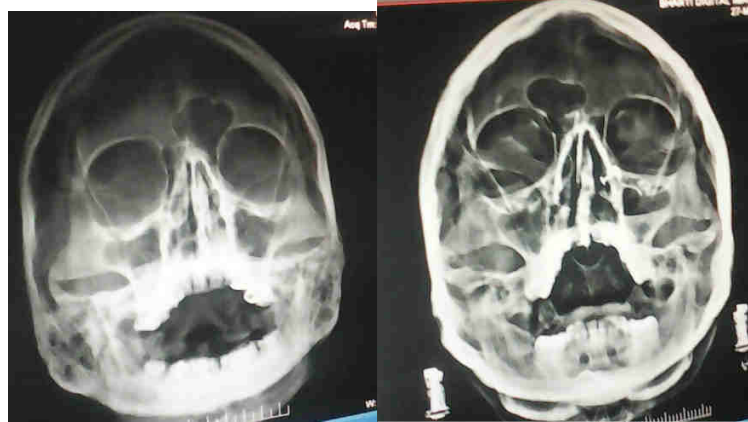


Fig b: Right sided Aplasia

Fig c: Left sided Aplasia

Table 2. Showing cases of Hypoplasia (Fig d, Fig e, Fig f)

S. No.	Particulars	Numbers	Percentage
2.	No. of cases with hypoplasia	22	50%
2.1	Bilateral hypoplasia	5	22.72%
2.2	Right sided hypoplasia	9	40.90%
2.3	Left sided hypoplasia	8	36.36%

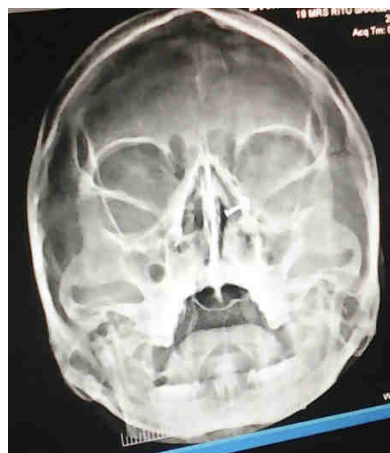


Fig d: Bilateral Hypoplasia

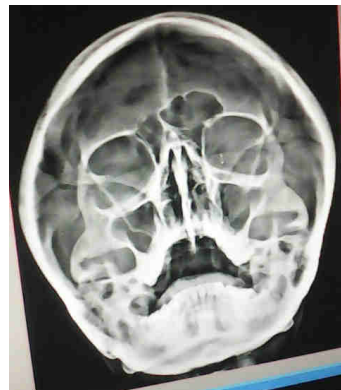


Fig e: Right sided Hypoplasia



Fig f: Left sided Hypoplasia

Table 3. Showing cases of one side Aplasia with other sided Hypoplasia (Fig g, Fig h)

S. No.	Particulars	Numbers	Percentage
3	No. of cases with one-sided aplasia & other sided hypoplasia	8	18.18%
3.1	Right sided aplasia with left sided hypoplasia	6	75%
3.2	Left sided aplasia with right sided hypoplasia	2	25%



Fig g: Right sided Aplasia with Right sided hypo

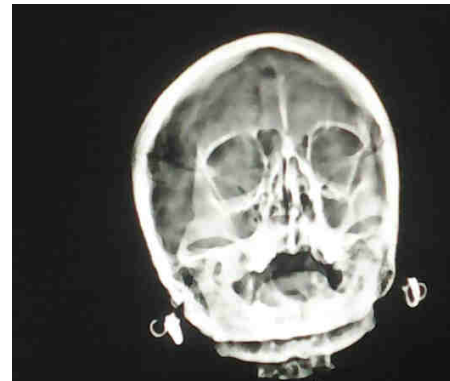


Fig h: Left sided Aplasia with Left sided hypoplasia

Discussion:

Enormous work has been done on the study of various parameters of the frontal sinus, especially on frontal sinus aplasia.

A study on the morphology of frontal sinus by Schuller (1943) suggested that the presence of a metopic suture was associated with the absence of the frontal sinus.⁽³²⁾

Krogman on his study on the morphology of frontal sinus in adult population, observed frontal sinus to be absent in 5% of the adult.⁽³³⁾

A survey on the prevalence of frontal sinus agenesis in the Canadian Eskimo samples has reported smaller sinuses in them than reported for Alaskan Eskimos or American Indian groups. 43% male and 40% female Canadian Eskimos also had bilateral frontal sinus agenesis.⁽³⁴⁾

Nowak and Mehls also reported unilateral absence of the frontal sinus in 7.4% for adults; more commonly on right (4.2%) as compared to left side (3.2%).⁽³⁵⁾

The frontal sinuses of 143 Eskimo skulls from two sites in the Hudson Bay region of Canada were examined radiographically. On average, the sinuses are small and often bilaterally absent. Alaskan Eskimos displayed significantly higher prevalence of agenesis i.e. 25% in males and 36% in females.⁽³⁶⁾

The absence of frontal sinus was found greater in females when compared to males in a vast study on Turkish population, Japanese population, and Alaskan Eskimos.⁽³⁷⁾

Yoshino et al in 1987 reported the unilateral absence of frontal sinus in 14.3% of males and 7.1% of female population. They also reported a higher frequency of right-sided aplasia in both males and females.⁽³⁸⁾

Spaeth et al. in 1997 noticed that agenesis of the frontal sinus was more frequent in women.⁽³⁹⁾

Ponde *et al* had found aplasia of the frontal sinus in 24.7% of the macerated skull samples of the Brazilian population in their study.⁽⁷⁾

Natsis K in their study on ‘**anatomical variations of Frontal sinus & orbital complications**’ dissected cranial cavities and the orbits of 18 GREECIAN cadavers which revealed complete aplasia of the frontal sinuses in a case of a 57-year-old female with.⁽¹⁷⁾

A Digital Radiographic Study on ‘**Frontal Sinus and Nasal Septum Patterns as an Aid in Forensics**’ was done on 149 individuals in the year 2008. Bilateral aplasia of frontal sinus was seen in 5.3% (4 males and 4 females) and unilateral aplasia was observed in 8.7% of the subjects.⁽⁸⁾

Tang *et al* [2009] reported non-existence of frontal sinus in Chinese Han population to the tune of 16.6%.⁽⁴⁰⁾

A study on the axial and coronal CT scans of the paranasal sinuses from a series of 588 Iranian patients revealed existence of unilateral and bilateral aplasia of frontal sinuses in 36 and 51 patients, respectively. The dominant sinus was on the left side in

68.24% of cases. The lower incidence of frontal sinus aplasia in this particular ethnic and geographical area relative to other populations emphasizes the effect of environmental and genetic factors on the development of frontal sinuses⁽⁴¹⁾

A study on PA cephalogram of 50 individuals showed that frontal sinus was absent (bilateral aplasia) in two individuals (4%) (One male and one female). Unilateral aplasia was seen in three individuals (6%) (One male and two females; two right and one left)⁽¹⁴⁾

A Study of the Frontal Sinus in Turkish Individuals Using Dental Volumetric Tomography revealed bilateral frontal sinus agenesis in 03 out of 410 subjects with male to female ratio as 1:2. Unilateral right-sided frontal agenesis was seen in the ratio of 2M:1F, whereas unilateral left sided agenesis, was noticed in the ratio of 0M:2F.(2011)⁽¹³⁾

A bilateral agenesis of the frontal sinus was seen in 8.32% of cases, and unilateral absence of the frontal sinus was observed in 5.66%. Of Iranian population by Computed tomographic scans in the axial and coronal planes of the frontal sinus.⁽⁴²⁾

In a radiological study on frontal sinuses by Neha Patil (2012), the observation revealed that the frontal sinus was absent bilaterally in 1% of the cases (1 person) as against 96% (96 persons) that showed the bilateral presence of the frontal sinus. Unilateral absence of a frontal sinus occurred in 3% of the cases (all three females,). Amongst them, the left frontal sinus was absent in one case and the right was absent in the other two.⁽¹⁶⁾

Hakan Korkmaz,(2013) reported total absence of all paranasal sinuses on CT (scan paranasal sinuses) in a 57-year-old woman, who presented with the complaints of occasional nasal stuffiness and chronic frequent bilateral headache attacks concentrating around both ears , accompanied nausea, fullness of the face and ears, and hearing loss during attacks&

tiredness around upper jaw during chewing.⁽⁴³⁾

Chetan Belaldavar et al in their radiological study regarding Assessment of frontal sinus among Indian adults found that out of 300 cases studied, the absence of frontal sinus was noticed in 12 subjects (4%), nine in females and three in males which included both unilateral and bilateral absence. Unilateral absence of sinus was noted in 1.3% (2 subjects) of males and 3.33% (5 subjects) of females; bilateral absence was noticed in 0.6% (1 subject) of male and 2.66% (4 subjects) of females.⁽¹⁰⁾

Absence of frontal sinuses was noted amongst a total of 100 subjects studied radiologically; 8% had bilateral absence which comprised of 4 males and 4 females, thereby finding no difference in the prevalence between males and females.⁽⁴⁴⁾

A bilateral aplasia of frontal sinus was seen in 5.3% (4 males and 4 females) and unilateral aplasia was observed in 8.7% of the subjects investigated radiologically by Verma P et al.⁽⁸⁾

A study by Sarita Choudhary et al on CT scan of head and neck region of north Indian population findings revealed aplasia of the frontal sinus in 6.6% subjects which included unilateral involvement in 5.3% whereas bilateral involvement in 1.3%. The prevalence of unilateral frontal sinus agenesis was higher in females (6.19%) as compared to males (4.12%). Both males and females showed a preponderance of left sided aplasia.⁽¹⁵⁾

A radiological study in the year 2015 by Gotlib T on 305 CT examinations revealed hidden unilateral frontal sinus aplasia (defined as lack of pneumatization of one frontal sinus, with increased pneumatization of the contralateral sinus, extending to the sagittal plane, crossing the lamina papyracea on the side of the aplastic sinus. Eleven out of 305 patients (3.6%) with hidden unilateral frontal sinus aplasia were identified, 5 on the left and 6 on the right side, in 5 female and 6 male patients. Twenty-four (7.8%) patients

with "regular" frontal sinus aplasia (without hyperplastic contralateral frontal sinus) were found, 4 with bilateral aplasia and 20 with unilateral aplasia].⁽²⁰⁾

A radiological study on 200 patients by BA Soman et al, revealed that 24 cases had bilateral aplasia and rudimentary frontal sinuses. The male to female ratio noted was 1:2.25. [2016]⁽⁹⁾

Conclusion: Our study on the aplasia/hypoplasia of frontal sinus by radiological method revealed a high prevalence of 29.33% in western UP belt population out of which **31.81%** had only **aplasia** (bilateral/unilateral), **50%** had only **hypoplasia** (bilateral/unilateral), and **18.18%** of case had **aplasia of one side with hypoplasia of another side**. All the three categories of variations are more common in **right-sided frontal sinuses**. Our observations recorded in western UP belt are in contrast to that made by Sarita et al⁽¹⁵⁾ in northern India (Lucknow) who reported an incidence of frontal sinus aplasia as 6.6% with more predominance on left side. A very high incidence of frontal sinus aplasia is documented in all Eskimos where it was primarily partially attributed to the cold climate and genetic factor.⁽¹³⁾ Western UP belt is a temperate zone having a hot climate. Hence a high incidence here could be attributed to factors other than climate & genetic ones which need to be investigated.

A thorough knowledge of frontal sinus is of immense importance for following reasons:

1. In adults, paranasal sinus agenesis is an uncommon anomaly that appears mainly in the frontal sinus and sphenoidal sinus.⁽⁴⁾
2. The variations in the anatomy of the frontal sinus may be critical for morphological or anthropological investigations.^(15, 9, 1)
3. When cranial base surgery is made in the frontal region or when supraorbital minicraniotomy is realized involvement of

the frontal sinus may become troublesome. The entrance by means of the craniotomy in the frontal sinus can lead to postoperative complications as CSF leakage, bone flap infections, besides the late consequences of meningitis and brain abscess.^(45, 7)

4. The frontal sinus is the one that is of most interest and significance in forensic science for personal identification due to its irregular shape and because of the individual characteristics which makes the frontal bone unique for every individual, just as with fingerprints. The chances of two people having similar pattern of frontal sinuses are very remote, hence this method of personal identification can be safely relied upon in forensic medicine, by comparing antemortem with post-mortem radiographs of suspected individual. However unlike fingerprints they are affected by pathology such as acute or chronic inflammation, some endocrine dysplasias, osteitis, and trauma. These are the limitations of this method of identification.^(46, 9)
5. In forensic medicine, the frontal sinus and other paranasal sinuses are important for establishing a reliable identification of unknown human remains based on the comparison of antemortem and post-mortem radiographic.⁽¹²⁾
6. Anatomical variations of the frontal sinuses may play a role in the correlation between frontal sinusitis and orbital complications. Such anatomical variations with unusual extension of the frontal sinuses above orbital roof may support the correlation between frontal sinusitis and the possible complications from the orbit and these cases may be considered as 'high risk' cases for orbital complications during a frontal sinusitis. Infection of the frontal sinus causing sinusitis can give rise to serious complications, as it is in close proximity to the orbit and cranial cavity (orbital cellulitis, epidural and subdural abscess, meningitis).^(17, 47)
7. The knowledge of frontal sinus aplasia is important, because complications may develop during endoscopic surgery for such genetic frontal sinus if not detected in advance. If one of the frontal sinus ostia cannot be found during sinus surgery, although this sinus and its recess can be seen on the thick-sliced coronal computed tomographic (CT) scans, genetic frontal sinus hidden by the extensive pneumatization of the contralateral sinus that is crossing the midline should be considered essentially. It may not be possible to foresee this variant preoperatively by endoscopic examinations or thick-sliced CT scans. If there is suspicion, thin-sliced CT scans with reconstruction will be ideal to confirm the agenesis of the frontal sinus and to avoid complications.^(13, 20)
8. A preoperative recognition of the frontal sinus morphology is a prerequisite for any successful surgical procedure because of individual anatomic variations. Therefore, the analysis of DVT images of the frontal sinus is a useful tool to identify its size and configuration and to minimize the risk factors associated with surgical procedures.⁽¹³⁾
9. Due to considerable variations in the shape, capacity, and asymmetry of the frontal sinus; a knowledge of frontal sinus anatomy and its variations is important for the diagnosis of acute and chronic sinus pathologies and for clinical and surgical procedures.⁽¹²⁾
10. A strong correlation is observed between sinus aplasia and ciliary process dyskinesia. The findings of aplasia/hypoplasia of the frontal and/or sphenoidal sinuses may be part of the spectrum of PCD - primary ciliary dyskinesia. However, SCD - secondary ciliary dyskinesia and other chronic respiratory disease can also cause sinus

aplasia and hypoplasia thus specific testing for PCD should always be performed.⁽⁴⁸⁾

Bibliography

1. Size and Position of Frontal Air Sinuses CARTA <https://carta.anthropogeny.org/moca/topics/size-and-position-frontal-air-sinuses>.
2. Singh A, Arlen D Meyers; Paranasal Sinus Anatomy: Overview, Gross Anatomy, Microscopic ... MEDSCAPE, emedicine.medscape.com/article/1899145-overview Updated: May 26, 2016
3. Porter GT. Paranasal Sinuses: Anatomy and Function - UTMB.edu <https://www.utmb.edu/.../paranasal-sinus-2002.../paranasal-sinus-2002-0...>
4. Pozve NJ, Sheikhi M, Khorasgani MA, and Pozve^{SJ} Aplasia and hypoplasia of the maxillary sinus: A case series. *Dent Res J (Isfahan)*. 2014 Sep-Oct; 11(5): 615–617.
5. Lundberg J.O.N., Szallas TFI, Weitzberg E, Rinder J^{et al} High nitric oxide production in human paranasal sinuses, *Nature Medicine* (1995)1, 370 - 373 .
6. Arnal JF, Flores P, Rami J, Espin MM, Bremont F, Aguilla MP et al . Nasal nitric oxide concentration in paranasal sinus inflammatory diseases. *Eur Respir J* 1999; 13: 307-312
7. Pondé, J. M.; andrade, R. N.; Via, J. M.; Metzger, P. & Teles, A. C. Anatomical variations of the frontal sinus. *Int. J.morphol.*, 26(4):803-808, 2008.
8. Verma P, Verma KG, Khosa R, Kumar S et al. Combined Use of Frontal Sinus and Nasal Septum Patterns as an Aid in Forensics: A Digital Radiographic Study *N Am J Med Sci*. 2015 Feb; 7(2): 47–52.
9. Soman B A, Sujatha GP, Ashok Lingappa A Morphometric evaluation of the frontal sinus in relation to age and gender in subjects residing in Davangere, Karnataka. *J Forensic Dent Sci*. 2016 Jan-Apr; 8(1): 57.
10. Belaldavar C, Kotrashetti VS, Hallikerimath SR, and Kale AD Assessment of frontal sinus dimensions to determine sexual dimorphism among Indian adults. *J Forensic Dent Sci*. 2014 Jan-Apr; 6(1): 25–30.
11. Asherson N. London: Lewis and Co; 1965. Identification by frontal sinus prints. A forensic medical pilot Survey.
12. Ruiz CR and Wafae anatomy-radiological and morphometrical study of the frontal sinus in humans. *braz. J. Morphol. Sci.* (2004) 21(1), 53-56
13. Çakur B, Sumbullu MA, Durna NB. Aplasia and Agenesis of the Frontal Sinus in Turkish Individuals: A Retrospective Study Using Dental Volumetric Tomography. *Int J Med Sci*. 2011; 8(3): 278–282 Published online 2011 Apr 8.
14. David MP, Saxena R. Use of the frontal sinus and nasal septum patterns as an aid in personal identification: A digital radiographic pilot study. *J Forensic Dent Sci*. 2010 Jul-Dec; 2(2): 77-80.
15. Choudhary S, Pasricha N 1, Sehgal G, Siddiqui MS¹ et al APLASIA OF FRONTAL SINUS: CT STUDY, *Int J Anat Res* 2015, Vol 3(4):1620-23. ISSN 2321- 4287.
16. Neha Patil N, Karjodkar FR, Sontakke S, Sansare K, Salvi R. Uniqueness of radiographic patterns of the frontal sinus for personal identification. *Imaging Sci Dent*. 2012 Dec; 42(4): 213–217.
17. Natsis K¹, Karabatakis V, Tsikaras P, Chatzibalas T, Stangos A, Stangos N. Frontal sinus anatomical variations with potential consequences for the orbit. Study on cadavers *Morphologie*. 2004 Apr; 88(280):35-8.
18. Paolo B, Fabio R, Cesare G, Massimiliano G, Giancarlo P Bilateral Hypoplasia of the Frontal Sinuses, *Journal of Craniofacial Surgery*: July 2013 - Volume 24 - Issue 4 - p 1502–1503

19. What is a hypo plastic frontal sinus? | Reference.
Com<https://www.reference.com> > Science > Human Anatomy.
20. Gotlib T, Kuźmińska M, Held-Ziółkowska M, Osuch-Wójcikiewicz E, Niemczyk K Hidden unilateral aplasia of the frontal sinus: a radio-anatomic study. *Int Forum Allergy Rhinol.* 2015 May; 5(5):441-4
21. Aydinlioglu A, Kavakli A, Erdem S. Absence of Frontal Sinus in Turkish individuals. *Yonsei Med J.* 2003; 44(2):215-8.
22. Aydinlioglu A, Kavakli A, Erdem S. Absence of frontal sinus in Turkish individuals. *Yoseni Medical Journal*, year 2003, Vol. 44, no. 2, pp.215-218.
23. Koertvelyessy T. Relationship between the frontal sinus and climatic conditions: a skeletal approach to cold adaptation. *Am J PhysAnthropol.* 1972; 34:161-72.
24. Hanson CL, Owsley DW. Frontal sinus size in Eskimo population. *Am J PhysAnthropol.* 1980; 53:251
25. **WabbaM** Frontal sinus | Radiology Reference Article | Radiopaedia.org <https://radiopaedia.org/articles/frontal-sinus>.
26. Scuderi AJ, Harnsberger HR and Boyer RS. Pneumatization of the paranasal sinuses: normal features of importance to the accurate interpretation of CT scans and MR images *American Journal of Roentgenology.* May 1993, VOLUME 160 NUMBER 5, P 1101-1104.
27. Hazem Abu Zeid Youset. , Paranasal Sinuses: Radiological Anatomy. CT anatomy of the paranasal sinuses. Published in: health and medicine on Oct 13, 2014 www.slideshare.net/hhazemyousef/ct-anatomy-of-the-paranasal-sinuses
28. Thiagarajan B, Narashiman NS Hypoplasia of all paranasal sinuses A case series and Literature review. *Otorhinology Online Journal* volume 2 Issue, 2, 2012 ISSN2250- 0359.
29. Frontal Sinus Aplasia symptoms, treatments & patient forums www.patientslikeme.com/conditions/1692-frontal-sinus-aplasia
30. Selarka B, Mehta R, Ludhwani S, Mansuri K et al. Conventional frontal sinus imaging – a tool in gender determination. *Bhavnagar University’s journal of dentistry (bujod) maharaja Krishna Kumarsinhji Bhavnagar University* Vol. 5 Issue-1 January 2015
31. Caldwell's view – Wikipedia https://en.wikipedia.org/wiki/Caldwell's_view
32. Schuller A. Note on the identification of skulls by X-ray pictures of the frontal sinuses. *Med J Aust.* 1943; 1:554-556.
33. Krogman WM. *The human skeleton in forensic medicine* 2nd ed. Vol. 20. Springfield III: Thomas; 1962.
34. Koertvelyessy T. Relationships between the frontal sinus and climatic conditions: A skeletal approach to cold adaptation. *Am J PhysAnthropol.* 1972; 337:161-7.
35. Nowak R, Mehls G. Die apblasien der sinus maxillaries und frontalesunterbesendererBerucksichtigun g der pneumatization beispalttragern. *AnatAnz* 1977; 142:441-50.
36. Hanson CL, Owsley DW. Frontal sinus size in Eskimo population. *Am J PhysAnthropol* 1980; 53:25.
37. Ikeda J. Inter-population variations of the frontal sinus measurements: Comparison between the Jomon and recent Japanese population. *J Anthropol Soc Nippon Suppl.* 1980; 90:91-104.
38. Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography. Its application to identification of unknown skeletal remains. *Forensic SciInt* 1987; 34:289-99.

39. Spaeth J, Krugelstein U, Schlondorf G. The paranasal sinuses in CT-imaging: development from birth to age 25. *Int J Pediatr Otorhinolaryngol.* 1997; 39:25–40.
40. Tang JP, Hu DY, Jiang FH, Yu XJ. Assessing forensic applications of the frontal sinus in a Chinese Han population. *Forensic Sci Int.* 2009; 183:104e1–3.
41. Rad MP, Dawoodi Y, Bakhshae M, Nabavi SA. The prevalence of frontal sinus aplasia in Mashhad, Northeast of Iran. *Iranian journal of otorhinology.* Article 5, Volume 21, Issue 55, April 2009, Page 29-32.
42. Sani S A D, Bavandi R, Esmaili M. Frontal Sinus Agenesis Using Computed Tomography. *The Journal of craniofacial surgery* · November 2011, 22(6):e48-51.
43. Korkmaz H, Korkmaz, M. Total aplasia of the paranasal sinuses. *Allergy & Rhinology.* 2013 Summer; 4(2): e105–e109
44. Verma S, Mahima V G, Patil K. Radio morphometric analysis of frontal sinus for sex determination. *J Forensic Dent Sciv* ,Sep-Dec 2014. 6(3): 177–182.
45. Ozgursoy OB, Comert A, Yorulmaz I, Tekdemir I, Elhan A, Kucuk B. Hidden unilateral agenesis of the frontal sinus: human cadaver study of a potential surgical pitfall. *Am J Otolaryngol* 2010; 31:231-4.
46. Neha, Mohan V, Kumar J S, Kumar SC. Morphometric Evaluation Of Frontal Sinus In Relation To Gender- A Forensic Study. *University J Dent Scie* 2015; 1(2): 7-11.
47. Frontal sinus Paranasal sinuses - Wikipedia https://en.wikipedia.org/wiki/Paranasal_sinuses
48. Pifferi M, Bush a, Caramella D, DiCicco M et al. Agenesis of paranasal sinuses and nasal nitric oxide in primary ciliary dyskinesia. *European Respiratory Journal* 2011 37: 566-571.