

The prevalence of frontal sinus agenesis (aplasia) among Kurdish populations of Erbil city

Soran M Karim ⁽¹⁾

Background and objective: The frontal bone contains a pair of air-filled hollow cavities called frontal sinuses, the size, shape and anatomic measurements and dimensions of the frontal sinuses are determined by the degree of its pneumatization. Any disturbance to the sinus during its early development stages could result whether in hypoplasia (underdevelopment) or aplasia (total lack) of the sinus either unilaterally or bilaterally. This study aims to investigate the prevalence of aplasia of the frontal sinus among Kurdish populations of Erbil city, in addition to assessment of the type of aplasia and gender impact on the condition if there is any.

Methods: This retrospective/radiological study was conducted on randomly selected PA (Caldwell view or occipito-frontal) plain radiographic images of 512 Kurdish individuals of mixed genders, ages ranging between 18 to 64 years and images were taken from the periods between April 2020 to May 2022.

Results: Careful examination of 512 assessed PA radiographs (with patient's ages ranging between 18 to 65 years) showed agenesis of the frontal sinus in 26 cases (5.16%), 17 females and 9 male cases), the type and location of the agenesis varied greatly as it was bilateral agenesis type only in 7 cases, and unilateral in remaining 19 cases, among the unilateral sinus agenesis cases 2 were observed to be agenesis of the left and 17 of the right frontal sinuses respectively.

Keywords: Prevalence, Frontal bone, Frontal sinus, Aplasia, Kurdish peoples, paranasal sinuses, anatomical variations.

⁽¹⁾Department of oral and maxilla-facial surgery/College of Dentistry / Hawler Medical University, Erbil, Iraq.

Corresponding Author: Soran M Karim

Email:soran.mustafa@hmu.edu.krd

INTRODUCTION

The accomplishment of maximum esthetic restorations is the most stressful procedure that is concerned by dentists. Although esthetics can be enhanced using different types of techniques, one of the most variable aspects of the human body is the structure of the nasal cavities and paranasal (PNS) sinuses^{1,7,11,16,18}. Understanding these anatomical characteristics is critical for many medical specialties and subspecialties, including otolaryngologists, maxillofacial surgeons, radiologists, oncologists, and many others, due to their intricate three-dimensional structure and several morphological variants^{11,18}. The paranasal sinuses are potential air-filled spaces located within the bones of the

skull and facial bones, they are centered around the nasal cavity (hence the naming) and serve many vital functions, they give resonance to the voice, humidify and warm-up the inspired air, to increase the surface area of the olfactory membrane of the nose interior, they also act as shock absorbent pads to absorb shock to the face and head thus they also serve mechanical protection function, lighten the weight of the skull and at the same time provide thermal insulation for the major parts of the central nervous system mainly the brain, they also contribute to facial growth^{2,3,4}. Four sets of paired sinuses are recognized: maxillary, frontal, sphenoid, and ethmoid^{2,3} and are actually named by their corresponding bones or the bones they pneumatize and expand within along the process of their de-

velopment and maturation till they get to their full size, they are inter-connected to each other on one hand and to the nasal cavity on the other hand^{4,5}. The frontal sinuses in infants are simply tiny chambers with no apertures (yet to develop), these develop due to the upward migration of ethmoid air cells through secondary pneumatization until early adolescence^{1,5}, because the left and right frontal sinuses grow independently (due to the presence of a bony barrier called inter-frontal septum in between them^{3,4}), there may be one fully developed and the other one could be hypoplastic, totally absent or even abnormally hyperplastic in some instances⁵. The frontal sinus is positioned behind the superciliary arch within the frontal bone, the two asymmetrical irregularly formed frontal sinuses (the right and left sinuses are generally asymmetrical in the same person¹) are complexly separated by a bony septum (an inter-osseous barrier) positioned approximately in the midline^{3,4}; the frontal sinus is highly vulnerable due to its close proximity to other anatomical structures, such as the anterior skull base or the roof of the orbital cavity³. The development of the frontal sinuses starts out from a single outgrowth among several others originated in frontal recess region of the nose, the frontal sinus may also develop from anterior ethmoid cells of the infundibulum but this is less common¹. The frontal sinuses are basically the only paranasal sinuses that are absent at birth, and their development is entirely postnatal, on average, these sinuses do not ascend into the frontal bone until about the age of 5-6 years and their development is highly variable and appears to start only after the second year of life^{16,18}. By the end of 4 and the beginning of 5 years, the cranial extent of the sinus reaches half the height of the orbital cavity and extends just superior to the top of the anterior ethmoid cells, the superior boundary of the frontal sinuses reaches the level of the roof of the orbital cavity by the age of 7 to 8 years, and by the age of 9 to 10 years, the sinuses extend fully up into the vertical compartment of the frontal bone and only after puberty do the final adult proportions of the sinus emerge, the volume of the frontal sinus is highly variable too, ranging from 0 to 40 ml, variability in the size and aspect of the frontal

sinus is usually found in individuals of the same age^{1,5,7}. Because of the presence of an inter-osseous barrier the left and right frontal sinuses develop independently, a significant asymmetry between these sinuses can arise in the same individual^{1,7}. The extent of pneumatization influences the size of the sinus and its anatomical relationship with the surrounding structures hence the configuration of the frontal sinus vary widely between individuals, and a frontal sinus may even never get formed in some people^{1,5,7,13}. Usually males have a larger frontal sinus than females, which accounts for the noticeable frontal bossing (forward bulging) seen in almost every male^{1,5}.

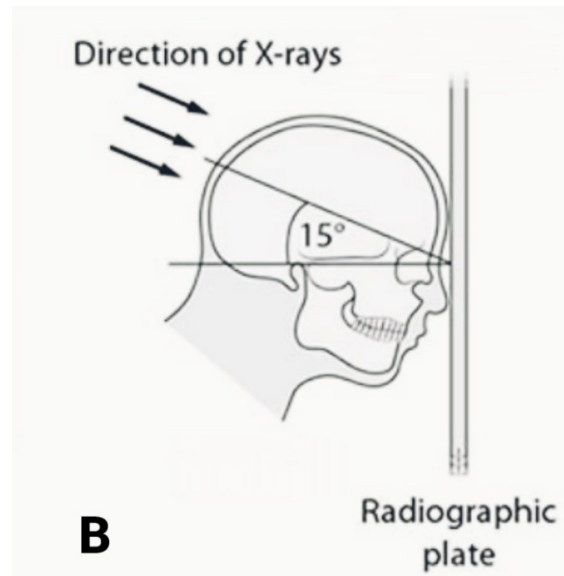
Frontal sinus aplasia is caused by a lack of pneumatization in the frontal bone and otolaryngologists in a specific kind of way should be aware of this type of variance because difficulties can arise after endoscopic surgery for an agenetic frontal sinus if it is not diagnosed in advance before the surgical operation^{10,11}. Although frontal sinus aplasia is rare in the medical literature and add to it the fact that the frequency of frontal sinus agenesis is variable between different populations depending on many influencing factors but still occasionally, one or both sinuses may be absent so having a sound knowledge about the anatomy of the sinus and its frequently occurring variances will surely let any operation go smoothly and reducing the risk of damage to the sinus itself and its neighboring structures hence reducing the chance of unplanned second surgical procedures^{11,14,15,22,23}. It has been established that radiographic imaging and sufficient knowledge of the frontal sinus anatomical variation are crucial and among essential parts of the pre-surgical requirements as well as the identification of individuals for forensic purpose^{14,15,12,23}. Therefore, the objective of this study was to investigate the prevalence of frontal sinus aplasia and agenesis PA (Postero-anterior/occipito-frontal/Caldwell view) x-ray images in a population of Kurdish individuals in Erbil city.

Methods

This retrospective multi-centric radiological study involved the assessment 512 occipito-frontal (PA) radiographs (also called Caldwell view) of Kurdish individuals of mixed genders (324 males and 188 females) ages ranging from 18 to 64 years (mean age being 41 years) and we utilized the digital data bases of the east emergency , west emergency and Hawler teaching hospitals in Erbil city at KRG/Iraq from the periods between April 2020 to May 2022 , radiographs were taken for a variety of medical reasons but the majority were of patients that originally subjected to radiography due to closed craniofacial injuries, after carefully examining each of the patient's x-ray films their medical records were also traced to exclude those aged less than 18 years , non-Kurdish individuals and those with history of open/compound or invasive craniofacial fractures. Caldwell's view (also known as Occipitofrontal view) is a radiographic view of the skull in which the X-ray plate is passing perpendicular to the orbitomeatal line (which is a positioning line used in skull radiography. The rays are oriented at 15-20° to the radiography plate and travel from behind the skull to its far anterior

aspect with the head being positioned in a way that the forehead and the nose touch the X-ray plate (**Figure 1 A & B**), it is widely used to improve visibility of the ethmoid and frontal sinuses^{5,6,8,9,20}.

This study was carried out following the applicable approved rules, regulations, and Helsinki declaration ethics standards, and was also approved by the relevant department's ethics committee and there were no potential risk or dangers linked with this study as there was no direct contact with the patients and to get more accurate readings the images were viewed on the computer screen with the help of a specialist radiologist. Frontal sinus aplasia was defined as the complete or incomplete, unilateral or bilateral, absence pneumatization of frontal bone with no ethmoid cells reaching above to the superior orbital margin. Each radiographical image was viewed on two PCs with 20.3 cm LCD monitors with the same screen resolution setting, sharpened accordingly in a darkened environment to get the most accurate readings. Since the frontal sinuses do not reach adult size until puberty^{1,7}, the minimum age in these cases was 18 years.



Figures 1 – A & B; Explaining the technique for Caldwell view of PA radiographs; note the direction of the x-ray beam, the angle of exposure and the head positioning .

Statistical analysis

Chi-square test was used and data analysis was performed utilizing SPSS (statistical package for social science) software version 23, simple descriptive statistics about the patients' ages, genders, and the presence or absence of unilateral (incomplete) or bilateral (complete) aplasia was supplied. Continuous data were presented as $M \pm SD$ (with m representing the mean and SD representing the standard of deviation), whilst categorical data were presented as numbers and frequencies and $P < 0.05$ was considered to be statistically significant. For statistical calculation of the value of the chi-square statistic. The formula for chi-square was utilized as follows:

$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

where;

χ^2 = Chi-Square value, O_i = Observed frequency, E_i = Expected frequency.

Results

In this study and out of the total sample size of ($n=512$); we observed agenesis of the frontal sinus in 26 cases (5.16%), among which 17 were observed to be in female patients (65.41% out of the total cases of agenesis, 3.4 % of the total sample size) and 9 among the male patients (34.67% out of the total cases of agenesis, 2.064 % of the total sample size), the type and location of the agenesis varied greatly as it was bilateral agenesis type only in 7 cases (26.96% out of the total cases of agenesis, 1.4 % of the total sample size) and they were 5 in females (17.86% among total sinus agenesis cases) and 2 (7.14% among the total sinus agenesis cases) among the male samples, and unilateral in remaining in 19 cases (73.64% out of the total cases of agenesis, 4.2 % of the total sample size) 14 of them were among females (2.73%) and just 5 of them were males (0.98%), among the unilateral sinus

agenesis cases 2 (0.36% out of the total sample size) were observed to be agenesis of the left and 17 (3.4% out of the total sample size) of the right frontal sinuses respectively. The 26 frontal sinus agenesis cases were aged between 20 to 65 years with a mean age of 42.5 years and the results are detailed below in (table-1-) and the female and male ratio distribution has been summarized in (Table-1-) while the distribution of the type of sinus agenesis is been shown in (figure-2-) and the representative samples of each type of agenesis accompanied by age and gender information have been shown in figures -3- and -4- respectively.

Table 1: shows the frequency of frontal sinus agenesis in our study

<i>Gender</i>	<i>n</i>	(FSA)	
		<i>Unilateral</i>	<i>Bilateral</i>
Female	17 (3.4%)	14 (2.73)	5 (0.98%)
Male	9 (2.064 %)	5 (0.98%)	2 (0.36%)
Total cases of agenesis	26 (5.16%)	19 (4.2 %)	7 (1.4 %)

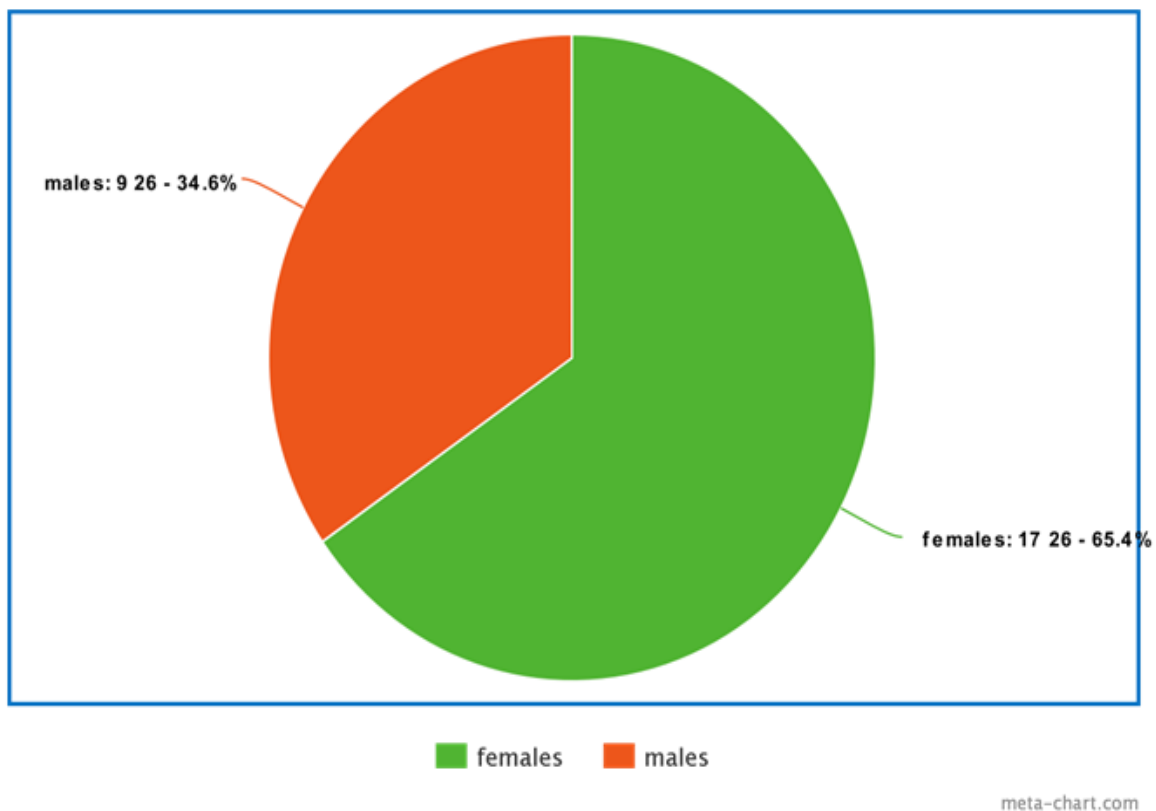


Figure-2- female and male distribution of the frontal sinus agenesis

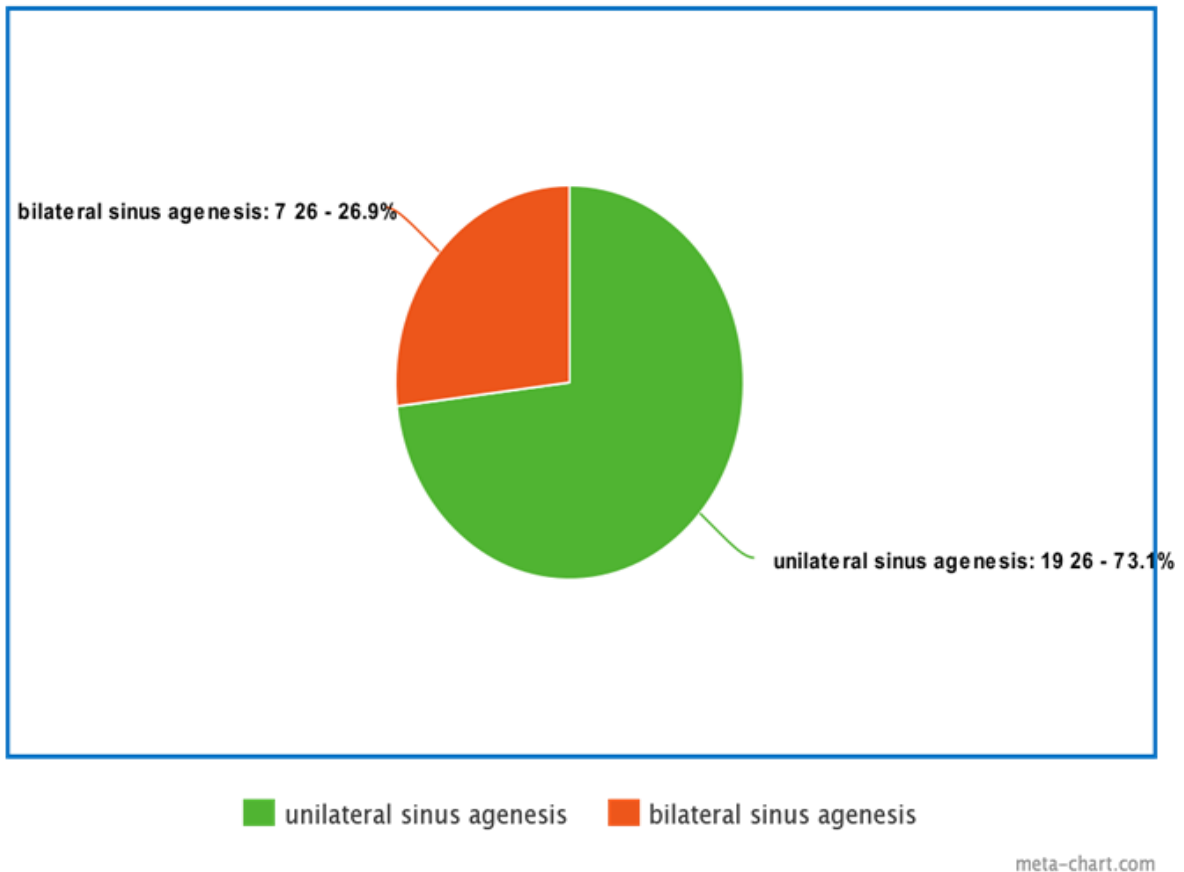


Figure-2- distribution of the type of frontal sinus agenesis.

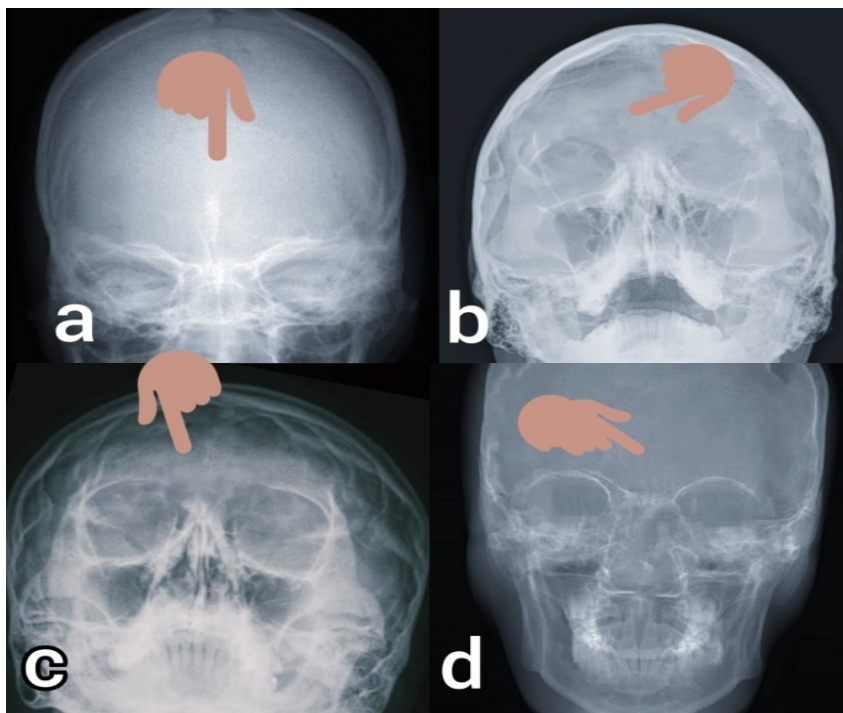


Figure-3- PA or OF (Caldwell) views of bilateral (complete) frontal sinus aplasia (agenesis) in; -a- 19 years old male coexisting along with another anatomical variation (persistent metopic suture), -b- in 34 years old female -c- 65 years old female -d- 38 years old male.

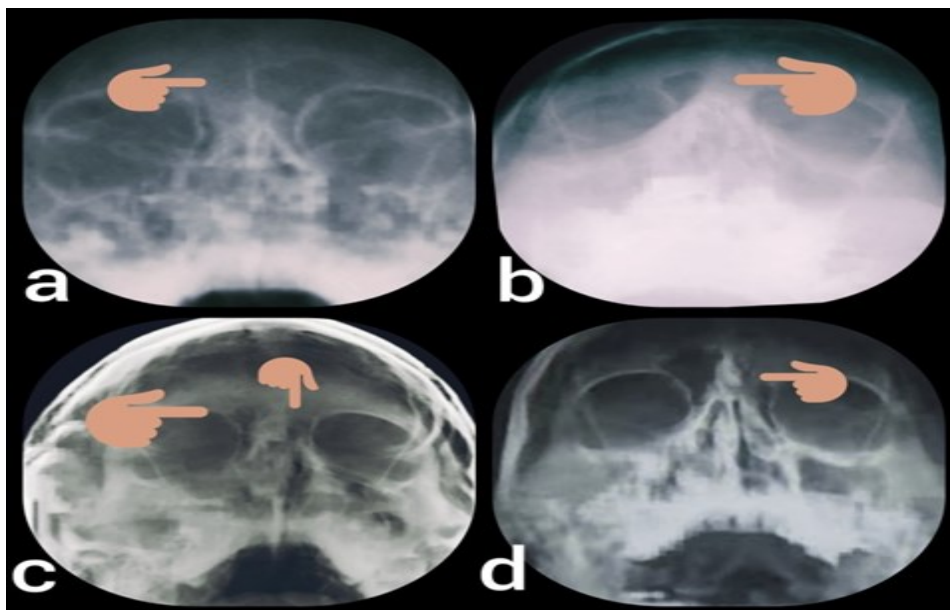


Figure-4- PA or OF (Caldwell) views of unilateral (incomplete) frontal sinus aplasia (agenesis) in; -a- 36 years old female -b- in 52 years old male –c- 35 years old female –d- 63 years old male.

Discussion

From the general perspective in clinical practice and according to documented literature the agenesis of the para-nasal sinuses (PNS) is considered to be relatively uncommon^{5,6,7,10,14,18} clinical condition that tend to appear majorly in the frontal sinuses (14%)^{9,12,13} and this has been linked to the fact the frontal sinus is the last PNS cavity to expand^{1,8,13}. Internationally it has already been established that frontal sinus aplasia (and aside from its type) appears in a higher proportion in certain populations than in others^{8,18,21,22}. The current study investigated the prevalence of agenesis of the frontal sinuses using PA x-rays in Kurdish individuals of Erbil city in KRG/Iraq and our data analysis showed that; the frequency of its occurrence is about 5.16%, which is relatively low in terms of significance and tends to be more frequent in females than males, the unilateral sub- type being more frequent than the bilateral subtype.

Data from international medical literature suggest that aplasia is present unilaterally in 13% and bilaterally in 7% of normal adults^{8,9,10,17,21,23}, regarding the type of sinus aplasia our study showed the same findings (with the unilateral subtype being more frequent than the bilateral subtype) with the difference in the frequency of oc-

currence which is higher than what we have observed in our study (5.16%) and this tends to be quite normal as the rate varies between races, and at the same time age, gender, geographical factors and climate as well may play a key role as influencing factors.

According to recent literature the only paranasal sinuses with post-natal pneumatization (frontal sinuses) are affected by being either underdeveloped (hypoplastic) or not developed at all (aplastic) and this is most probably caused by (CPNUAI); chronic post-natal upper airway infection or inflammation, which could be linked to premature ossification of the cartilage surrounding the PNS recesses hence leading to total agenesis or under development^{11,12}. Recent observations of frontal sinus aplasia in a significant proportion of adult patients with persistent airway infection actually confirm these concepts and theories^{5,14,18}. Sever chronic upper respiratory infections in addition to habitual nasal breathing are required for sinus hypoplasia or aplasia to occur^{19,24}. Diving deeper into recent medical literature data regarding frontal sinus agenesis of nearby geographical regions and studies that were done in neighboring countries, in recent research of 942 instances in Saudi Arabia²², frontal

sinus agenesis was found in 7.4% of the cases. While in a study that was conducted in Jordan the prevalence of bilateral frontal sinus aplasia was observed only in 3.7% of cases

among Jordanian individuals 23. In another study among the Turkish population, the frequency of unilateral frontal sinus aplasia was 2.13% 21, another study that was conducted in New Zealand reported that the frequency of aplasia or the absence of the frontal sinus was 5.07% 10, another study reported frequency of frontal sinus absence to be 5.38 % 9 among peoples of Oman sultanate, another recent study of 831 cases in Saudi Arabia revealed that frontal sinus agenesis was detected in 6.83% 22 and the outcomes of those three studies are relatively close to the findings of our study

(5.16% among Kurdish peoples of Erbil).

The majority of studies proposed that agenesis of the frontal sinus aside from its types is more frequent in females 6,8,11,12,16 24 which is actually same as our findings and it's what we observed too (table-1-). Aydinlioğlu 17 reported that the incidence of the right unilateral agenesis of the frontal sinus was higher than that of the left unilateral agenesis which also happens to agree with our study's outcomes (0.76% out of the total sample size were observed to be agenesis of the left and 3.4% out of the total sample size of the right frontal sinuses respectively). Table-2- showing the frequency of occurrence of frontal sinus agenesis across different populations around the world researched by different authors. It has been scientifically proven that there is a direct relationship between the mechanical stresses of mastication and frontal sinus enlargement and if there is persistence metopic suture, the frontal sinuses are usually small (sinus hypo-genesis or underdeveloped sinus or even absent (sinus agenesis) 1,5,7.

The differences in frequency of frontal sinus agenesis between Kurdish populations and other ethnic populations could be attributed to many factors like the differences in sample size as well as differences in observation techniques, methodologies, approaches and equipment utilized by every single research, also factors such as age, gender, hormones, ethnic craniofacial configurations, and environmental factors such as climatic conditions and even pre-existing local inflammations like chronic upper respiratory tract infections ^{5,9,11} may play a significant role in controlling frontal sinus development and its overall configuration within each population, as well as contributing to any future abnormal developments of the frontal sinus.

Conclusion

Our study showed the frequency of occurrence of frontal sinus agenesis among Kurdish population to be relatively low, yet it must be taken into consideration during the pre-surgical planning on frontal sinus or any other relevant anatomical landmarks. Because of diverse inter-individual anatomic variations of the frontal sinus the preoperative recognition and assessment of the sinuses is required for any successful surgical procedure, identifying any existing agenesis in the frontal sinuses minimize the risk factors associated with surgical procedures, therefore, careful analysis of P.A. or occipito-frontal images of the sinus is an extremely useful tool to identify the size and configuration of the sinus, also the presence of sinus agenesis can be used as a personal forensic record. In conclusion the low incidence of frontal sinus aplasia in our study among this particular ethnic group (Kurdish peoples) in this particular geographic area (Erbil city of KRG Iraq) relative to different other populations is reflective and emphasizes the effect of environmental factors, climate and genetics on the development of the frontal sinuses.

Conflicts of interest

The authors reported no conflicts of interests

Table 2: the frequency of frontal sinus agenesis (aplasia) across different ethnic groups by researched by different authors

Author(s)/ researcher(s)	Ethnic groups/ race	n (sample seize)	Frequency of frontal sinus aplasia %
Soran M K	Kurdish	512	5.16
Al-Shaikh et al	Saudi Arabs	942	7.14
Al-Balas et al	Jordanians	421	3.7
Chakur et al	Turkish	629	2.13
Keast et al	NewZealand	362	5.07
AL-Abri et al	Oman sultanate	216	5.38
Ozgursoy et al	Nigerians	831	6.83
Hoffman and Sommer	Europeans	674	3.9
Spaeth at al	Mexicans	322	8.07
Egessbo et al	Russians	423	3.53
Hanson and Ousley	Eskimo	183	1.78
Kim et al	Chinese	973	8.2

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