IMAGISTIC INVESTIGATIONS OF FRONTAL SINUS ARCHITECTURE AND PATHOLOGY – AN INTERDISCIPLINARY APPROACH TO PRACTICAL DENTISTRY

Ana Maria Fătu[1+], Magda Ecaterina Antohe[1*], Laura Elisabeta Checherita[2*], Liliana Georgeta Foia[3+], Victor Vlad Costan[3], Ovidiu Stamatin[1+], Andrei Rosu[3+], Silvia Teslaru[2+], Iulian Costin Lupu[1+], Sorina Mihaela Solomon[2], Irina Gradinaru[1+], Cristian Marius Toma[4+], Cristina Gena Dascalu[5+], Laurian Francu[3+], Mihai Bogdan Vascu[2]

1 Department of Implantology, Removable Dentures, Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, 700115 Iasi, Romania;
2 2 nd Dental Medicine Department, Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, 700115 Iasi, Romania;
3 1st Dental Medicine Department, Faculty of Dental Medicine, "Grigore T. Popa "University of Medicine and Pharmacy, 700115 Iasi, Romania;
4 Department for Institutional Development "Grigore T. Popa "University of Medicine and Pharmacy, 16 Universității Street, 700115, Iasi, Romania;
5 Department of Medical Informatics and Biostatistics, Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, 16 Universității Street, 700115, Iasi, Romania;

* Corresponding author: Magda- Ecaterina Antohe , e-mail: magda.antohe@umfiasi.ro;
Laura Elisabeta Checherita, e-mail: checherita.laura@gmail.com;

+ All authors have the same scientifical contribution and equal rights .

Abstract: In order to determine the effects of frontal sinus morphology on the morpho-functionality of the dento-maxillary apparatus and the therapeutic management of pathologies in the orthodontic or maxillofacial surgery area, paraclinical evaluation is extremely important. During time, radiography - a relatively old method, allowed complex explorations of the extreme cephalic area, providing details of cephalometric and facial indexes and information regarding the pneumatization and neuro- and viscera-cranium at the same time. Aim: This manuscript focuses on the correlation of elements related to craniofacial anomalies, in which frontal sinus malformations hold a particularly important place, with various dental anomalies which are particularly important aspects in optimizing the diagnostic and therapeutic protocol in both, orthodontic and orthognathic surgical approaches. Materials and methods: We set out to examine the frontal sinus, including a number of 112 patients, aged 4 to 78 years old, with malocclusions, the research being performed in the Radiology Clinic of Emergency Clinical Hospital "Sf. Spiridon" Iasi, during 2018-2020. We used in our research the landmarks represented by the frontal median septum and the upper orbital margin, on the basis of which we calculated the dimensions of the frontal sinus. The cases were as follows: 66 women (58,9%) and 46 men (41,1%), and age distribution was as follows: •4 - 9 years (20 cases – 17,9%); •10 - 19 years (22 cases – 19,6%); •20 - 45 years (31 cases – 27,7%); •46 - 60 years (19 cases – 17,0%); •over 60 years (20 cases – 17,9%). Results and discussions: The data obtained in our study are superimposable on those found in the literature, noting a frequency of absence of bilateral frontal sinus in 9,8% of cases, the elements of specificity belonging to the percentage of 6,1% for women and 15,2% for men, all cases being between 5-15 years. There are not significant differences between the planimetric measurements at patients with sinusitis compared with the others; instead, we found statistically significant differences between the planimetric measurements concerning the right sinus as well as the left sinus at the 3 classes of malocclusion – the patients in the I-st class have the smallest sinuses, the patients in the II-nd class have intermediary mesurements, while the patients in the III-rd class have the biggest measurements of the sinuses. Conclusions: In dental practice, cascading effects are extremely important, starting from frontal sinus malformations, which lead to different types of dento-dental anomalies, the implications being found in specific orthodontic therapy and orthognathic surgery.

Keywords: frontal sinus; computer tomography; imaging in dentistry; malocclusion; oral complex rehabilitation;

1. Introduction

The involvement of the frontal sinus in the development of craniofacial architecture is particularly important, its appearance being associated with age over 2 years, continuing its evolutionary path with increasing dimensions, as these increase significantly during adolescence. The characteristics of the frontal sinuses, regarding size and shape have a wide range of variability and differ from individual to individual. It is important to note that there are situations in which the frontal sinus never forms. It is also known that frontal sinus sizes are larger in males than in females. In terms of morphology and aesthetics, the frontal sinus is responsible for the prominent frontal bossa seen in many men [1]. The morphological peculiarities of the frontal sinus, as well as aspects of pathology grafted at this level, contribute to difficulties in the differential diagnosis made between ophthalmological, neurological, or oro-maxillofacial surgery territory. The left and right frontal sinuses are separated by an intersinus septum.

The peculiarities of the frontal sinus are extremely important in anthropology, contributing definitively to human recognition, to the identification of belonging to an ethnic group with well-defined characteristics [2].

Preuschoft et al. found in their studies that the development of frontal sinuses was a consequence of the need for biomechanical balance of cranial architecture [3]. In the range of factors influencing frontal sinus morphology, we can note the importance of the magnitude and direction of masticatory forces that are associated with mechanical stress and pneumatization effects at this level.

In order to determine the effects of frontal sinus morphology on the morpho-functionality of the dento-maxillary apparatus and the therapeutic management of pathologies in the orthodontic or maxillofacial surgery area, paraclinical evaluation is extremely important. Contemporary dental practice is practically governed by digitization and paraclinical assessment using 3D techniques, but we are also obliged to bring back into the present-day assessment using 2D techniques associated with the unfavorable socio-economic criteria of a significant proportion of patients [4].

Craniofacial anomalies are a diverse group of deformities regarding the growth of the head and facial bones. Anomaly is a medical term meaning "irregularity" or "different from normal." These abnormalities are present at birth (congenital), and there are numerous variations. Some are mild, and some are severe and require surgery. Some CFAs are associated with anomalies elsewhere in the body, which can be serious. This category may include the absence of the maxillary sinus, either on its own or associated with other clinical entities [5].

Computed tomography (CT) and magnetic resonance imaging were developed to help get around this 2-D/3-D problem, but both have their own limitations. These modalities acquire numerous images (sometimes in the thousands) that are thin anatomical slices. Being so small and thin reduces the amount of anatomic overlap, but the radiologist needs to regard all the slices in order to detect any abnormalities, while trying to “fuse” them into a single mental representation of the entire 3-D anatomic region that has been scanned. As the radiologist views subsequent slices, a picture of the 3-D lung structure evolves, and the linear extent of the individual blood vessels can be perceived. In a single slice, however, it is difficult to tell whether a single white speckle is a tumor visible in only that slice or a blood vessel that will extend beyond that slice through the others. The accurate and efficient interpretation of medical images relies on a host of factors. Clearly the technologies and methods used to acquire, process, transmit, store and display the image and associated data are critical, but they are only one-half of the equation. In the end, the final diagnostic interpretation and recommendations for subsequent further action represent the clinician’s responsibility. Ideally, we would like to believe that all decisions rendered by competent clinicians are correct, but the interpretation task is not always easy or black and white. Thus, decisions are not always absolutely conclusive, they are often formulated with plausible alternatives, and errors in interpretation can and do occur regularly [6]. The discipline of medical image perception seeks an improved understanding of the perceptual factors that underlie the creation and interpretation of medical images, with the belief that improved diagnostic performance with the use of imaging devices can be achieved by the development of systems that are optimized for the interpretation of visual diagnostic information. Perception research can identify specific reasons for missed diagnoses, thereby helping to train physicians and eliminate diagnostic errors, and clarifying situations in which errors are a consequence of fundamentally ambiguous information rather than poor reader performance.

The working hypothesis is based on the central idea that frontal sinus morphogenesis is influenced by the forces acting in the oro-maxillofacial territory, and to the same extent elements of variability in frontal sinus morphology can influence the development of the dento-maxillary apparatus.

The goal of this article is to provide a short review of the history of the discipline of medical image perception, to highlight key research areas, and provide a look toward the future regarding the role that medical image perception research will continue to fill as imaging technology in medicine advances and develops.

2. Materials and Methods

We set out to examine the frontal sinus, including a number of 112 patients, aged 4 to 78 years old, with malocclusions, the research being performed in the Radiology Clinic of Emergency Clinical Hospital "Sf. Spiridon" Iasi, during 2018-2022.

We used in our research the landmarks represented by the frontal median septum and the upper orbital margin, on the basis of which we calculated the dimensions of the frontal sinus.

The cases were as follows: 66 women (58,9%) and 46 men (41,1%), and age distribution was as follows: •4 - 9 years (20 cases – 17,9%); •10 - 19 years (22 cases – 19,6%); •20 - 45 years (31 cases – 27,7%); •46 - 60 years (19 cases – 17,0%); •over 60 years (20 cases – 17,9%).

The article focuses on the correlation of elements related to craniofacial anomalies, in which frontal sinus malformations occupy a particularly important place, with the various dental anomalies, which are particularly important aspects in optimizing the diagnostic and therapeutic protocol in both orthodontic and orthognathic surgical approaches. The results obtained after imaging measurements, both on classical radiographs and on actual reconstructive imaging evaluations, provide us with statistically significant correlations between frontal sinus architecture and skeletal anomalies.

Measurements performed on both classic frontal normal radiographs and digital radiographs targeted three parameters involved in frontal sinus assessment, namely length, width and height, as well as the influencing symmetry aspects that precede orthognathic surgery or orthodontic approaches.

The statistical analysis was performed in SPSS 27.0. The qualitative data were reported as absolute values and percentages and the quantitative data were reported as averages, standard deviations and ranges. The comparisons between samples were performed using the Chi-squared test for qualitative data and the t-Student, Mann-Whitney, Kruskal-Wallis and Wilcoxon Signed Ranks tests for quantitative data, according to the results of Shapiro-Wilks tests of normality. The accepted level of significance was $p < 0,05$.

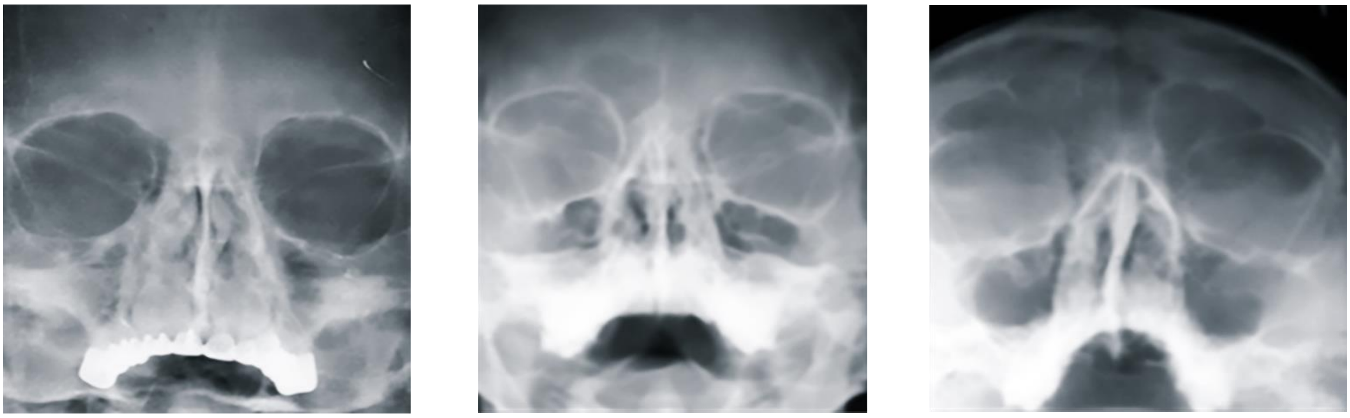
All patients included in the study signed the informed consent for participation, and the study received the institutional ethical committee approval (The study was approved by the Ethics Committee of "Grigore T. Popa" University of Medicine and Pharmacy of Iasi (Protocol Code No. 547.10012012).

3. Results

Absence of the frontal sinus

The data obtained in our study are superimposable on those found in the literature, noting a frequency of absence of bilateral frontal sinus in 9,8% of cases, the elements of specificity belonging to the percentage of 6,1% for women and 15,2% for men, all cases being between 5-15 years.

Frontal sinus aplasia in adults was found in 3 cases (5%), aged over 45 years. Absence of the unilateral frontal sinus I came across in one case of a 67-year-old woman. Sinus hyper-pneumatization was found in 5 cases, 3 in women and 2 in men, aged between 45 and 83 years.



(**a**) absence of bilateral frontal sinus (female, 47 years); (**b**) absence of unilateral frontal sinus (female, 67); **(c)** frontal sinus hyper-pneumatization (female, 45 years old)

Figure 1. Radiological image of the frontal sinus

Planimetric measurement of the frontal sinus

The frontal sinus can be detected with radiological tests from the age of 4 years. A major development takes place between 10 and 19 years old, when it comes to adult values. Over 60 years, as a result of the osteoporosis process, a growth is observed in sinus area due to reduced orbital cortex. In adulthood, the sinus area variations are important and may occur due to chronic local inflammatory factor [7].

The impact of knowing the anatomical variations of the frontal sinus is particularly important in the therapeutic management of sinus pathology and especially in the surgical approach to this pathology.

We measured the length, width and height of frontal sinuses, the results being presented in Table 1.

Table 1. Planimetric measurements of the frontal sinuses, by age ranges and genders

	Age range	Total		Male		Female	
		M ± SD	Range	M ± SD	Range	M ± SD	Range
Right sinus length L	4-9 ys	7,975 ± 2,4057	5,7 ÷ 14,2	8,767 ± 3,0865	6,8 ÷ 14,2	7,183 ± 1,3045	5,7 ÷ 8,8
	10-19 ys	14,600 ± 2,2845	9,1 ÷ 18,2	16,920 ± ,7430	16,4 ÷ 18,2	13,771 ± 2,0608	9,1 ÷ 15,9
	20-45 ys	20,594 ± 2,1318	16,3 ÷ 24,5	20,060 ± 1,8446	18,4 ÷ 24,5	21,094 ± 2,3156	16,3 ÷ 23,2
	46-60 ys	28,653 ± 3,6380	24,5 ÷ 36,4	33,360 ± 2,8510	30,8 ÷ 36,4	26,971 ± 2,0634	24,5 ÷ 30,3
	> 60 ys	36,885 ± 3,4255	31,1 ÷ 44,2	39,650 ± 2,8005	36,5 ÷ 44,2	35,042 ± 2,4515	31,1 ÷ 39,6
	Total	22,709 ± 9,7153	5,7 ÷ 44,2	23,644 ± 10,8254	6,8 ÷ 44,2	22,121 ± 8,9900	5,7 ÷ 39,6
Left sinus length L	4-9 ys	9,950 ± 3,1405	6,4 ÷ 14,4	8,167 ± 2,6212	6,4 ÷ 12,2	11,733 ± 2,6823	8,2 ÷ 14,4
	10-19 ys	13,779 ± 2,4344	8,8 ÷ 18,2	13,120 ± ,9094	12,2 ÷ 14,1	14,014 ± 2,7793	8,8 ÷ 18,2
	20-45 ys	24,739 ± 5,9342	15,8 ÷ 35,6	25,080 ± 6,8621	16,5 ÷ 35,6	24,419 ± 5,1240	15,8 ÷ 28,6
	46-60 ys	29,258 ± 3,9499	22,2 ÷ 34,6	28,460 ± ,5814	28,2 ÷ 29,5	29,543 ± 4,6006	22,2 ÷ 34,6
	> 60 ys	30,440 ± 2,5634	26,6 ÷ 36,6	32,038 ± 2,7161	28,4 ÷ 36,6	29,375 ± 1,8873	26,6 ÷ 32,2
	Total	22,899 ± 8,5324	6,4 ÷ 36,6	22,805 ± 9,4924	6,4 ÷ 36,6	22,958 ± 7,9503	8,2 ÷ 34,6
Right sinus width W	4-9 ys	15,075 ± 2,6220	12,0 ÷ 21,1	15,900 ± 3,4560	13,4 ÷ 21,1	14,250 ± 1,2438	12,0 ÷ 15,5
	10-19 ys	23,426 ± 4,0800	17,0 ÷ 32,7	29,020 ± 3,2376	25,6 ÷ 32,7	21,429 ± 1,8685	17,0 ÷ 23,7
	20-45 ys	29,997 ± 5,1128	24,0 ÷ 38,0	35,100 ± 1,1964	33,8 ÷ 38,0	25,213 ± ,6975	24,0 ÷ 25,9
	46-60 ys	32,484 ± 4,4584	26,2 ÷ 39,2	39,080 ± ,0837	39,0 ÷ 39,2	30,129 ± 2,1935	26,2 ÷ 33,0

	> 60 ys	38,130 ± 3,0039	33,4 ÷ 43,7	41,075 ± 1,4390	40,0 ÷ 43,7	36,167 ± 1,9378	33,4 ÷ 39,3
	Total	29,066 ± 8,0833	12,0 ÷ 43,7	33,103 ± 8,4947	13,4 ÷ 43,7	26,527 ± 6,7227	12,0 ÷ 39,3
Left sinus width W	4-9 ys	17,025 ± 4,1039	11,7 ÷ 25,0	20,000 ± 3,7051	16,6 ÷ 25,0	14,050 ± 1,4433	11,7 ÷ 15,2
	10-19 ys	21,353 ± 3,8771	15,2 ÷ 27,5	26,980 ± ,3834	26,6 ÷ 27,5	19,343 ± 2,0586	15,2 ÷ 21,8
	20-45 ys	30,242 ± 3,1889	23,0 ÷ 37,5	30,913 ± 3,2089	27,6 ÷ 37,5	29,613 ± 3,1392	23,0 ÷ 34,0
	46-60 ys	38,432 ± 2,6376	34,8 ÷ 43,0	38,440 ± ,4336	38,0 ÷ 39,0	38,429 ± 3,0943	34,8 ÷ 43,0
	> 60 ys	45,250 ± 3,9543	39,0 ÷ 50,9	41,188 ± 1,6788	39,0 ÷ 42,9	47,958 ± 2,2825	43,2 ÷ 50,9
	Total	31,512 ±10,1966	11,7 ÷ 50,9	31,803 ± 7,4740	16,6 ÷ 42,9	31,329 ± 11,6429	11,7 ÷ 50,9
Right sinus height H	4-9 ys	11,325 ± 2,4739	8,3 ÷ 17,0	12,583 ± 2,8833	10,1 ÷ 17,0	10,067 ± 1,1622	8,3 ÷ 11,4
	10-19 ys	15,821 ± 2,5249	11,5 ÷ 18,8	18,000 ± ,5385	17,5 ÷ 18,8	15,043 ± 2,5019	11,5 ÷ 18,1
	20-45 ys	22,810 ± 2,1535	18,4 ÷ 26,4	23,620 ± 2,3001	19,4 ÷ 26,4	22,050 ± 1,7508	18,4 ÷ 23,5
	46-60 ys	28,411 ± 2,3870	25,2 ÷ 32,6	31,200 ± ,9566	30,3 ÷ 32,6	27,414 ± 1,8831	25,2 ÷ 30,0
	> 60 ys	35,770 ± 2,3593	30,4 ÷ 39,9	36,438 ± 2,1974	33,3 ÷ 39,9	35,325 ± 2,4499	30,4 ÷ 37,7
	Total	23,750 ± 8,3104	8,3 ÷ 39,9	24,803 ± 8,2559	10,1 ÷ 39,9	23,089 ± 8,3430	8,3 ÷ 37,7
Left sinus height H	4-9 ys	12,833 ± 3,7488	7,7 ÷ 20,7	15,867 ± 2,5766	14,2 ÷ 20,7	9,800 ± 1,4819	7,7 ÷ 11,6
	10-19 ys	22,779 ± 4,2684	13,6 ÷ 30,1	24,260 ± ,8764	23,3 ÷ 24,9	22,250 ± 4,8832	13,6 ÷ 30,1
	20-45 ys	29,081 ± 2,5336	25,7 ÷ 32,2	26,640 ± ,9898	25,7 ÷ 29,5	31,369 ± ,6183	30,2 ÷ 32,2
	46-60 ys	35,463 ± 3,4382	31,0 ÷ 41,9	32,440 ± 1,4502	31,0 ÷ 34,4	36,543 ± 3,3091	32,3 ÷ 41,9
	> 60 ys	47,220 ± 4,0446	39,4 ÷ 52,1	46,063 ± 5,2693	39,4 ÷ 52,1	47,992 ± 2,9938	43,0 ÷ 52,1
	Total	30,757 ±11,0416	7,7 ÷ 52,1	29,405 ± 10,0856	14,2 ÷ 52,1	31,608 ± 11,6014	7,7 ÷ 52,1

Table 2. Comparison between the sizes of Left – Right sinuses

	Age range	Total p - Value	Male p - Value	Female p - Value
Right sinus length vs. Left sinus length	4-9 ys	0,107	0,246	0,027*
	10-19 ys	0,398	0,041*	0,826
	20-45 ys	0,001**	0,014*	0,014*
	46-60 ys	0,468	0,041*	0,096
	> 60 ys	0,000**	0,011*	0,002**
	Total	0,919	0,171	0,177
Right sinus width vs. Left sinus width	4-9 ys	0,059	0,027*	0,339
	10-19 ys	0,000**	0,221	0,001**
	20-45 ys	0,883	0,001**	0,001**
	46-60 ys	0,001**	0,041*	0,001**
	> 60 ys	0,001**	0,888	0,002**
	Total	0,001**	0,022*	0,000**
Right sinus height vs. Left sinus height	4-9 ys	0,071	0,027*	0,248
	10-19 ys	0,000**	0,041*	0,001**
	20-45 ys	0,000**	0,001**	0,000**
	46-60 ys	0,000**	0,041*	0,001**
	> 60 ys	0,000**	0,011*	0,002**
	Total	0,000**	0,000**	0,000**

Wilcoxon Signed Ranks test; * p<0,05 statistically significant; ** p<0,01 statistically highly significant

We found statistically significant differences between the left and right sinuses width and height, globally as well as separated by genders and not significant differences between sinuses lengths. Still, the sinuses lengths are significantly different at the girls between 4-9 ys, the boys between 10-19 ys, all patients between 20-45 ys and over 60 ys, as well as at the males between 46-60 ys (table no. 2). It follows that the frontal sinus dimensions vary according to age and gender; the frontal sinuses height is higher in males (result also supported by a series of previously studies, [25,26,27,28]).

We made a classification of frontal sinuses in small, medium-sized and large according to the criteria proposed by Stokovic, Ozdemir et al. [29, 30], which evaluate the extent of pneumatization of the orbital roof in the coronal plane. The small sinuses are characterized by orbital roof pneumatization absent or localized only in the medial third; the medium sinuses are characterized by pneumatization of the medial third and a portion of the central third of the orbital roof and the large sinuses are characterized by pneumatization of the medial, central and a portion or all of the lateral third of the orbital roof; we also classified the frontal sinuses according to their morphological features, like shape, symmetry or relation.

The results of the evaluation are presented in Table 3. The most frequent type of frontal sinus is medium-sized, on the right side (68,3%) as well as on the left side (69,3%); on the next place we find the small sinuses (17,8% - right sinus, 10,9% - left sinus) and on the last place the large sinuses (13,9% - right sinus, 19,8% - left sinus). There are no statistically significant differences between genres in which concerns the classification on sinuses types reported on the right and the left side. Most sinuses are bilateral (96,0%); we reported 4 patients with unilateral sinus (4,0%), all males. Most sinuses are symmetrical (81,2%), the percentage of asymmetrical sinuses being slightly bigger in males (20,5%) than in females (17,7%), but without statistically significant differences; all sinuses are separated and also, most sinuses are fan-shaped (60,4%), followed by irregular (28,7%) and quadrangular shapes (10,9%), without significant differences between genders.

Table 3. Frontal sinus morphological evaluation

	Total n(%)	Males n(%)	Females n(%)	p-value
Right sinus type				0,288
Small	18 (17,8)	4 (10,3)	14 (22,6)	
Medium	69 (68,3)	29 (74,4)	40 (64,5)	
Large	14 (13,9)	6 (15,4)	8 (12,9)	
Left sinus type				0,643
Small	11 (10,9)	4 (10,3)	7 (11,3)	
Medium	70 (69,3)	29 (74,4)	41 (66,1)	
Large	20 (19,8)	6 (15,4)	14 (22,6)	
Sinus structure				0,020*
Bilateral	97 (96,0)	35 (89,7)	62 (100,0)	
Unilateral	4 (4,0)	4 (10,3)	0 (0,0)	
Sinus symmetry				0,729
Symmetrical	82 (81,2)	31 (79,5)	51 (82,3)	
Asymmetrical	19 (18,8)	8 (20,5)	11 (17,7)	
Sinus relation				-
Separation	101 (100,0)	39 (100,0)	62 (100,0)	
Fusion	0 (0,0)	0 (0,0)	0 (0,0)	
Sinus shape				0,747
Fan-shaped	61 (60,4)	25 (64,1)	36 (58,1)	
Irregular	29 (28,7)	11 (28,2)	18 (29,0)	
Quandrangular	11 (10,9)	3 (7,7)	8 (12,9)	

Chi-squared test; * p<0,05 statistically significant; ** p<0,01 statistically highly significant

We also reported in our sample of patients the presence of sinusitis and the malocclusion class; we found 33 cases of sinusitis (32,7%) at the level of the right sinus and 28 cases of sinusitis (27,7%) at the level of the left sinus; also 17 patients (16,8%) have malocclusion 1st class, 56 patients (55,4%) have malocclusion 2nd class and 28 patients (27,7%) have malocclusion 3rd class. We studied the possible relations between the presence of these pathologies and the frontal sinus morphological evaluation (Table 4).

Table 4. The relation between the frontal sinus morphological evaluation and the pathology reported

	Sinusitis			Malocclusion class			
	Absent (%)	Present n(%)	p-value	I-st class n(%)	II-nd class n(%)	III-rd class n(%)	p-value
Right sinus type			0,235				0,000**
Small	15 (22,1)	3 (9,1)		13 (76,5)	5 (8,9)		
Medium	45 (66,2)	24 (72,7)		4 (23,5)	51 (91,1)	14 (50,0)	
Large	8 (11,8)	6 (18,2)				14 (50,0)	
Left sinus type			0,342				0,000**
Small	9 (12,3)	2 (7,1)		9 (52,9)	2 (3,6)		
Medium	52 (71,2)	18 (64,3)		8 (47,1)	52 (92,9)	10 (35,7)	
Large	12 (16,4)	8 (28,6)			2 (3,6)	18 (64,3)	
Sinus structure			0,919				0,093
Bilateral	46 (95,8)	51 (96,2)		17 (100,0)	55 (98,2)	25 (89,3)	
Unilateral	2 (4,2%)	2 (3,8)			1 (1,8)	3 (10,7)	
Sinus symmetry			0,122				0,663
Symmetrical	42 (87,5)	40 (75,5)		15 (88,2)	44 (78,6)	23 (82,1)	
Asymmetrical	6 (12,5)	13 (24,5)		2 (11,8)	12 (21,4)	5 (17,9)	
Sinus shape			0,132				0,005**
Fan-shaped	25 (52,1)	36 (67,9)		4 (23,5)	37 (66,1)	20 (71,4)	
Irregular	15 (31,3)	14 (26,4)		8 (47,1)	16 (28,6)	5 (17,9)	
Quandrangular	8 (16,7)	3 (5,7)		5 (29,4)	3 (5,4)	3 (10,7)	

Chi-squared test; * p<0,05 statistically significant; ** p<0,01 statistically highly significant

There are no relations between the morphological aspects of frontal sinus and the presence of sinusitis; the patients with sinusitis, in the most cases, have medium sinuses (72,7% - right, 64,3% - left), bilateral (96,2%), symmetrical (75,5%) and fan-shaped (67,9%). The patients with I-st class of malocclusion usually have small sinuses (76,5% - left), while the patients with II-nd class of malocclusion usually have medium sinuses (91,1% - left, 92,9% - right) and the patients with III-rd class of malocclusion have medium or large sinuses; these differences are statistically significant and are similar with those obtained in other studies (Rossouw et al. [29]). In agreement with the opinions formulated by these researchers, the importance of frontal sinus evaluation can materialize as an extremely important predictor of mandibular growth disorders, highlighting the direct link between frontal sinus growth and the association of these dimensions with Angle class III malocclusion. The mentioned aspects are critically important in the correct oral rehabilitation of the patient for both orthodontic therapeutic and orthognathic surgical trajectories (fig. 5-8).

Table 5. The relation between the frontal sinus planimetric measurements and the pathology reported

	Sinusitis			Malocclusion class			
	Absent m ± SD	Present m ± SD	p-value	I-st class m ± SD	II-nd class m ± SD	III-rd class m ± SD	p-value
Right sinus length	21,763 ± 9,6801	24,658 ± 9,6410	0,213[a]	9,976 ± 3,4863	21,843 ± 6,9774	32,171 ± 6,8355	0,000**[c]
Right sinus width	28,068 ± 8,0883	31,124 ± 7,7925	0,106[a]	17,335 ± 3,6778	29,800 ± 6,2691	34,721 ± 5,7441	0,000**[c]
Right sinus height	22,956 ± 8,3295	25,388 ± 8,1516	0,187[a]	12,512 ± 2,9845	23,034 ± 5,6716	32,007 ± 5,8047	0,000**[c]
Left sinus length	23,515 ± 8,6540	21,293 ± 8,1381	0,236[a]	12,235 ± 3,8510	23,193 ± 8,1977	28,786 ± 4,0305	0,000**[c]
Left sinus width	31,512 ± 10,0962	31,511 ± 10,6423	0,999[b]	17,600 ± 3,7310	30,713 ± 7,2487	41,557 ± 6,4784	0,000**[c]

Left sinus height	30,414 ± 10,6808	31,654 ± 12,0905	0,946[a]	15,759 ± 5,6506	29,545 ± 6,4674	42,289 ± 8,0510	0,000**[c]

[a]Mann-Whiyney test; [b]T-Student test; [c]Kruskal-Wallis test; * p<0,05 statistically significant; ** p<0,01 statistically highly significant

There are also not significant differences between the planimetric measurements at patients with sinusitis compared with the others; instead, we found statistically significant differences between the planimetric measurements concerning the right sinus as well as the left sinus at the 3 classes of malocclusion – the patients in the I-st class have the smallest sinuses, the patients in the II-nd class have intermediary measurements, while the patients in the III-rf class have the biggest measurements of the sinuses (Table 5).

4. Discussions

From an organogenetic point of view, the frontal sinus can be considered to develop concomitantly with the anterior ethmoidal cells, with which it forms a fronto-ethmoidal pneumatic complex [8]. Prenatal development of this complex begins in the 4th month of intrauterine development, with the development of the nasal cavity [9]. The epithelium in the lateral wall proliferates in the primordial mesenchyme of the nostrils. Two diverticula appear in the middle of the nasal meatus: one develops the primordia that will form the fronto-ethmoidal complex, and the other will form the primordia of the maxillary sinus. These differences will take place in the week 19-22, remaining this way until birth [10]. The postnatal development of the fronto-ethmoidal complex is related to the development of the respiratory system, aspects that may influence the growth and development of dental arches [11]. Pneumatization of the frontal bone depends on two factors:

- interactions between the epithelium and the location of osteoclasts;
- separation of the two cortical plates of the frontal bone.

On radiological images, the sinus front cannot be identified before the age of 3, and development can be considered completed around the age of 20 [12].

Sinus air less than 0.8 cm^2 is equivalent to absence of the sinus, a percentage of around 10%. At the Eskimos, the frequency of frontal sinus absence is larger (25-30%), probably an adaptation to the climatic conditions [13].

The individual variations include genetic structure, hormones, cranio-facial configuration, age, to which are added the environmental factors (climatic, local inflammatory conditions) [14,15,16].

Hyper-pneumatization of the frontal bone is the result of the antero-posterior growth, due to the diploid of the frontal bone. Sometimes the pneumatics extends cranio-caudally, towards the zygomatic process [17,18,19].

The frontal sinus can be considered a component of the fronto-ethmoidal complex dynamic, and hence the possibility of transmitting inflammation of the frontal sinus to the fronto-ethmoidal cells, and from here to the meningo-cerebral territory.

Computed tomography is a very useful complementary examination for the detection of brain disorder set by craniofacial growth. It represents a complex imaging examination through the details provided for both soft tissues and the bony ones [20,21,22].

Compared to teleradiography profile, which provides only one projection of cephalometric landmarks, CT images provide 2D details of a selected plan of the region of interest, ensuring the possibility of 3D reconstruction capture of the entire investigated area. This is ensured (by reporting to the 3D space) improved accuracy of the location of cephalo-metric points than any other method.

This imaging technique based on densitometry creates a 2D image of a plane of section region of the investigated region, by measuring the attenuation of an X-ray beam that passes through the anatomical region, by calculating the corresponding absorption coefficient.

The obtained image quality relies on both, the densitometric principle used and the work with the collimated beam, therefore limited to the simple thickness of the layer to be examined. This fact ensures the elimination of the structural noise by limiting to an axial plane (as a result of the addition of multiple planes).

CT examination of the craniofacial territory is performed by axial section (transverse) joints 10mm thick, with 10 mm interval, usually 8-12 sections, parallel to the orbito-meatal plane. Fine details can be obtained by increasing the number of sections and by shorter time intervals between them (2-5 mm).

CT scan of the jaw and the mandible can be taken with Dental CT and Spiral CT [23,24].

Digital image processing of CT sections allows 2D reconstructions (of plans of interest other than those investigated) even 3D images. To this end, the Dentascan program is very effective in dentistry.

In this regard, graphically illustration (figure 2 and 3) 3D renderings of point, linear, angular landmarks and planar obtained from a set of 24 images of CT sections, are suggestive.

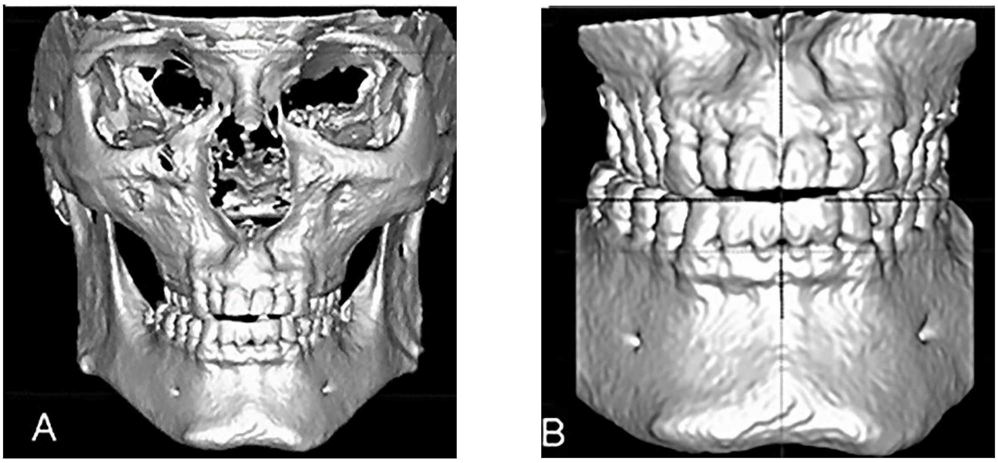


Figure 2. Craniofacial image previous (A) and detail (B) through it I 3D reconstruction images.

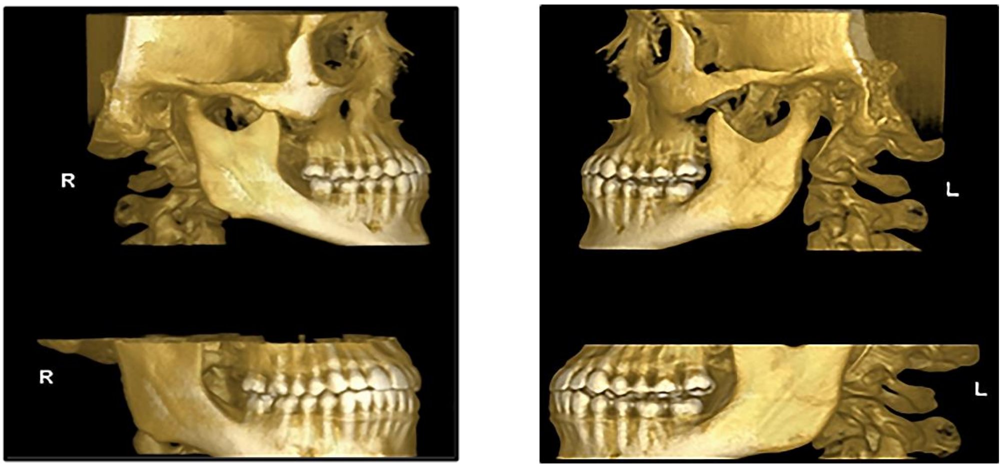


Figure 3. Lateral craniofacial images obtained by 3D reconstruction

The 3D evaluation of the frontal sinus is extremely accurate in providing all the anatomical details of the frontal sinus, a particular role being played by the detection of recessive cells at the anterior or posterior level, these elements being found in the age range 20-45 years.

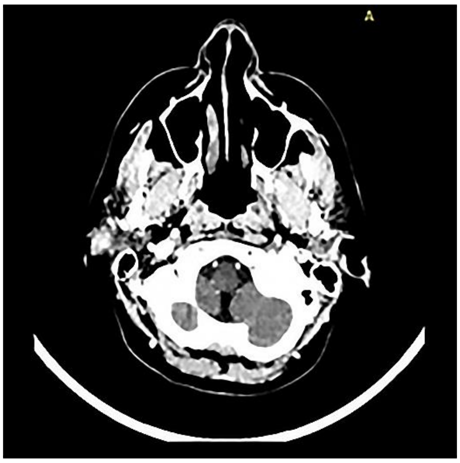


Figure 4. CT scan, axial section

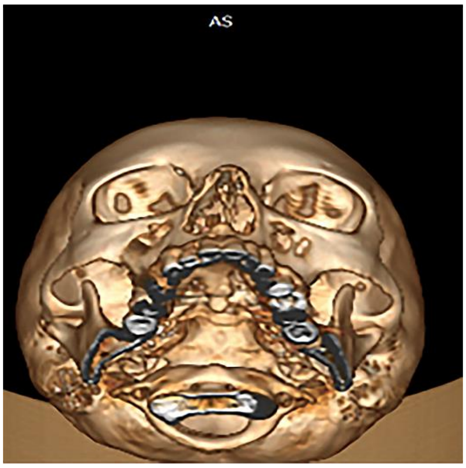


Figure 5. CT scan, bone reconstruction

Figure 6. Right frontal sinus aplasia, left frontal sinus hypoplasia, coronal section

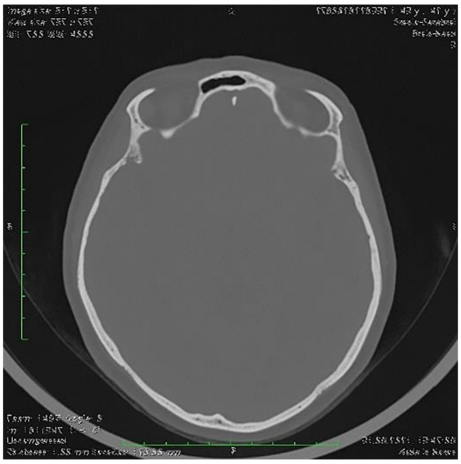


Figure 7. Right frontal sinus aplasia, left frontal sinus hypoplasia, axial section

Frontal sinus agenesis was found in three patients, aspects correlated with overt metabolic dysfunction. The low percentage of frontal agenesis is in agreement with the data provided in the literature, where the number of patients is low; these elements are important for planning analyses for interventions in the maxillofacial territory, as well as bringing considerable input for anthropometric studies that differ from one human race to another.

Anthropometric measurements correlated with vertical occlusion dimensions in relation to posture and centrics, subsequently served the complex oral rehabilitation process by applying according to the Kennedy printing classes predominantly Class I and II ,75% with the related changes, the rest being interested in grades III and IV.[26-29]

Thus, diagnostic corroborations serve the therapeutic attitude in order to rehabilitate the resulting measurements, being of a real support in restoring homeostasis level at the stomatognathic level. In dental practice, cascading effects are extremely important, starting from frontal sinus malformations, which lead to different types of dento-dental anomalies, the implications being found in specific orthodontic therapy and orthognathic surgery. It is also particularly important to take into account the various associations of these entities with local edentulous changes that are superimposed on the occlusal level, respectively on the cranio-mandibular relationship, the clinical end remaining in the register of complex oral rehabilitation[30-33].

5. Conclusions

Radiological evaluation provides important data on the different types of craniofacial anomalies, with particular attention to the frontal sinus. The classical radiological examinations, through the measurements performed, provide feasible information about the width, height and symmetry of the frontal sinus, a contribution of accuracy and rigour is provided by 3D reconstructions, namely the use of the Dentscan type of analysis which is the basis for a more accurate analysis of these types of cranial changes.

For maxillofacial therapy and orthodontic rehabilitation, of major importance is the correlation between maxillary sinus size and skeletal anomaly classes, with statistically significant elements being found between increased frontal sinus size (both left and right sides – length, width and height) and the occurrence of class 3 Angle anomalies. Class 3 Angle anomalies are also significantly associated with fan-shaped sinus, while Class 1 Angle anomalies are associated with irregular sinus. The sinusitis presence is not significantly associated with specific sinus types or measurements, even if we noticed slightly bigger lengths, widths and heights of right sinus in patients with sinusitis.

The frontal sinus variations are in accordance with the age range, the general condition and the patients gender, and hence we could notice that in the age range 4-9 years the frontal sinus height is much higher in boys than in girls, for the age range 10-19 years the differences between frontal sinus dimensions are even more prominent; with increasing age we noticed aspects of atrophy of the frontal sinus, correlated with changes in the interocclusal ratios and the installation of edentulousness with different types of complications.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations:

SS - stomatognathic system
DSSS - dysfunctional syndrome of the stomatognathic system
TMJ - temporo-mandibular joint
CT - computer tomography
CBCT - cone-beam computed tomography
2D - bidimensional space perspective
3D - tridimensional space perspective
CFA - craniofacial anomalies
MRI - magnetic resonance imaging

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