RESEARCH ARTICLE

The relationship of anterior occlusion and skeletal variables with the frontal sinus index: An analytical cross-sectional study

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Abstract

Objective: To determine the relationship of anterior occlusion and skeletal variables with the frontal sinus index.

Method: The retrospective, analytical, cross-sectional, study was conducted from July to November 2020 at Dr Ishrat-ul-Ebad Khan Institute of Oral Health Sciences and Dow Dental College, Dow University of Health Sciences, Karachi, and comprised data from 2015 to 2018 related to pre-treatment lateral cephalograms for determining frontal sinus index and other cephalometric variables. The dental casts were observed for incisor classification. Patients with Class I incisors formed the comparison group, while the rest comprised 5 malocclusion groups. The frontal sinus was traced, and the sinus index was calculated. Data was analysed using STATA 15 and R 3.5.1.

Results: Of the 240 subjects, there were 40(16.66%) in each of the 6 groups; 155(64.6%) females and 85(35.4%) males. The mean age of the sample was 21.33±3.52 years (range: 16-29 years). The mean sinus index was higher in all malocclusion groups than the comparison group, but it was significantly higher only in Class II division 2 and anterior open bite groups ($p<0.05$). The only exception to the trend was Class II division 1 with and without contact in which the value was lower ($p>0.05$). The anterior cranial base length, sella-nasion mandibular plane angle, and upper incisor palatal plane angle significantly affected the frontal sinus index ($p<0.05$).

Conclusion: The frontal sinus index could be considered an indicator of harmonious anterior occlusion.

Keywords: Frontal sinus, Cephalometry, Dental occlusion, Malocclusion. (JPMA 74: 1224; 2024)

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Introduction

Understanding the relationship of the stomatognathic system with craniofacial complex provides better understanding and application in orthodontics. With advancements in computed tomography (CT) technology, there is increasing evidence regarding the critical role of paranasal sinuses in the growth of craniofacial complex and orthodontic treatment.[1-4] The paranasal sinuses that occupy significant space in the cranium are thought to develop in response to mechanical stresses.[5] Due to the location, unique morphology and different clinical manifestation, the frontal sinus is considered complex among all paranasal sinuses.[6] It has been stated that the septum in the frontal sinus seems to be showing that stress is distributed in the midline, and reaches the frontal sinus.[7] The magnitude and direction of force from the masticatory system is a critical stress inducer, thereby affecting the pneumatisation of sinuses.[8] The frontal sinus is a type of paranasal sinus that is readily appreciable on the lateral cephalograms routinely obtained for treatment planning in orthodontics. It has already been an area of interest for clinicians to understand its correlation with growth and skeletal maturity in orthodontic patients. The occlusal forces generated from the anterior dental arches dissipate along the medial orbital periphery to the frontal sinus, leading to variation in the frontal sinus size.[9]

There is limited literature regarding the relationship of frontal sinus size with the anterior occlusion and other skeletal variables, with only a few studies[8,10] having taken relationship of frontal sinus size with occlusion into account. Prado et al. reported that changes in occlusion and jaw relationships could affect the frontal sinus size,[10] thereby signifying the frontal sinus as an indicator of harmonious occlusion. The Broadbent concept of cephalometric radiography[11] expanded the role of lateral cephalogram in craniofacial research. The frontal sinus identifiable on lateral cephalogram has gained researchers' attention to assess its relationship with the stomatognathic system. Although the lateral cephalogram is easily accessible to clinicians, the inherent drawback of two-dimensional (2D) cephalometry, such as magnification, is inevitable. To overcome these shortcomings, the sinus index, a ratio of height and width of the frontal sinus, is taken into account.[12] In a nutshell, the harmonious occlusion will result in better dissipation of forces through maxillofacial trajectories depicted by smaller frontal sinus

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size on the radiograph.[8]

The current study was planned to determine the relationship of anterior occlusion and skeletal variables with the frontal sinus index.

Materials and Methods

The retrospective, analytical, cross-sectional, study was conducted from July to November 2020 at Dr. Ishrat-ul-Ebad Khan Institute of Oral Health Sciences and Dow Dental College, Dow University of Health Sciences (DUHS), Karachi, and comprised data from 2015 to 2018 related to pre-treatment lateral cephalograms for determining frontal sinus index and other cephalometric variables. The dental casts were observed for incisor classification.

After approval from the DUHS ethics review board, the sample size was calculated using Process Automation Software System (PASS) V.11 with 95% confidence interval (CI), 80% power of test and level of significance (α)=0.05, H0: β0=10.61 and HA: β1=15.61, *r*1=0.5 and standard deviation (SD)=17.726.8 The calculated sample size was rounded off on the higher side to ensure equal distribution among the study groups.

The sample was raised using simple random sampling technique from among the records of approximately 2,400 patients in the institutional database related to the targeted period. Patients, or in case of children aged <18 years, their parents or legal guardians had already signed consent about their data being used for any future research purposes before beginning the treatment.

Those included were patients aged 16-30 years having healthy periodontium on orthopantomogram (OPG). Those excluded were patients having a history of seasonal allergy or any ear, nose, throat (ENT) disease, those with anterior teeth having dilacerations, peg laterals, traumatised or impacted teeth in anterior maxillary or mandibular arch, or any other tooth anomaly visible on OPG. Also excluded were those with aplasia or obliteration of frontal sinus visible on lateral cephalogram, and those having a history of bone metabolic disorders or receiving drugs that alter bone quality.

The retrieved data was divided into comparison group having those with Class I incisors and 5 malocclusion groups comprising Class II division 1 incisors with contact, Class II division 1 incisors without contact, Class II division 2 incisors, Class III incisors with reverse overjet, and anterior open bite malocclusion (Table 1).

All study measurements were performed by tracing the frontal sinus seen on lateral cephalogram on tracing sheet of 0.003-in matte acetate with 0.5 mm lead pencil. The sinus index was calculated by dividing the maximum height by the maximum width of the frontal sinus. The height was taken as the distance (mm) between the most superior point on the frontal sinus to the most inferior point on the frontal sinus, whereas the maximum width was taken as the distance (mm) between the most anterior point of the frontal sinus to the most posterior part of the frontal sinus. The values of other independent variables were assessed by tracing lateral cephalograms that included anterior cranial base length sella-nasion (SN) distance (mm), sella-nasion mandibular plane angle (SNMP), maxillomandibular plane angle (MMA), upper incisor sella-nasion angle (UISN) and upper incisor palatal plane angle (UIPP) (Figure).

A single investigator traced and determined the sinus index and other cephalometric variables from all the calibrated cephalometric radiographs. To estimate intra-examiner reliability, 30 randomly selected cephalograms were retraced and remeasured by the same investigator three months following the initial measurements. To estimate inter-examiner reliability, the same selected radiographs were retraced and remeasured by another investigator.

The frontal sinus index (FSI) was the dependent variable in the study, while SN, SNMP, MMA, UISN, UIPP incisor relationship class were the independent variables.

Data was analysed using STATA 15 and R 3.5.1. Intra-

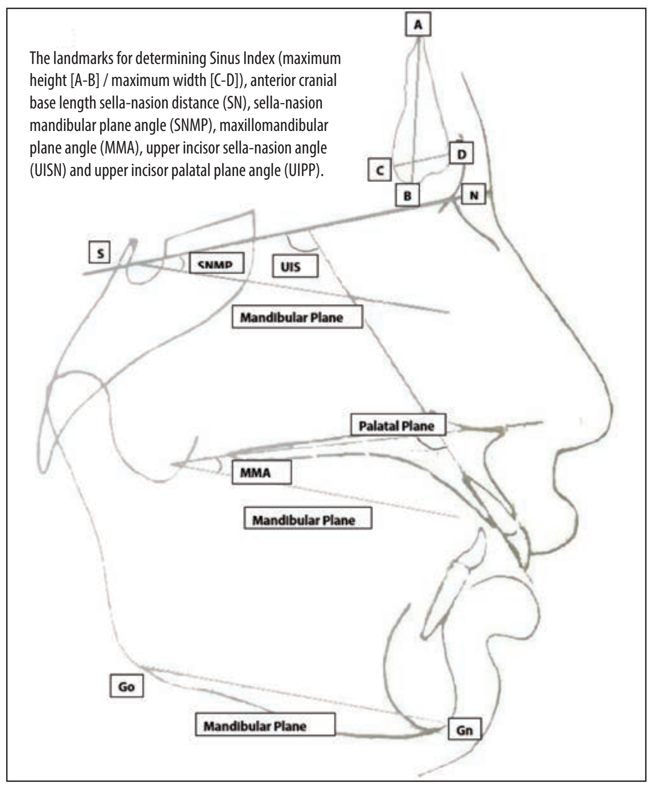

Figure: Image representation of cephalometric measurements.

examiner and inter-examiner reliability was determined using intraclass correlation coefficient (ICC), with the values ≥0.995 and ≥0.994, respectively, indicating excellent reliability. Mean and SD was calculated for FSI. Data normality was assessed using Kolmogorov-Smirnov test. Non-parametric analysis of variance (ANOVA) using Kruskal-Wallis test was applied for mean comparison of the sinus index among the groups. For pairwise comparison, Dwass-Steel-Critchlow-Fligner test was used due to non-normality of sinus index values among the classes.

The correlation matrix was generated using Spearman's correlation to assess the relation of sinus index with independent variables except incisor classes. To further clarify the influence of variables on sinus index, multiple quantile regression analysis was carried out. The coefficient significance was reported using t-stats and p-value. The level of significance was set at $p<0.05$.

Results

Of the 240 subjects, there were 40(16.66%) in each of the 6 groups; 155(64.6%) females and 85(35.4%) males. The mean age of the sample was 21.33±3.52 years (range: 16-29 years). The mean sinus index was higher in all malocclusion groups than the comparison group, but it was significantly higher only in Class II division 2 and anterior open bite groups ($p<0.05$). The only exception to the trend was Class II division 1 with and without contact in which the value was lower ($p>0.05$) (Table 2).

There was a significant but weak positive correlation of SNMP and MMA, as well as significant and weak negative correlation of UISN and UIPP was found with FSI ($p<0.05$). A significant but weak negative correlation of SNMP and MMA was found with SN, and MMA had a significant and strong positive correlation with SNMP ($p>0.05$). There was a significant strong positive correlation of UISN with UIPP (Table 3).

Table-3: Correlation matrix for sinus index and lateral cephalometric variables.

Parameter	Sinus Index	SN	SNMP	MMA	UISN	UIPP
SINUS INDEX	-	-	-	-	-	-
SN	-0.04 (0.49)	-	-	-	-	-
SNMP	0.29 (<0.001**)	-0.25 (<0.001**)	-	-	-	-
MMA	0.22 (0.001**)	-0.23 (<0.001**)	0.85 (<0.001**)	-	-	-
UISN	-0.24 (<0.001**)	0.11 (0.09)	-0.06 (0.34)	0.11 (0.09)	-	-
UIPP	-0.27 (<0.001**)	0.12 (0.06)	-0.007 (0.91)	0.09 (0.16)	0.92 (<0.001**)	-

**Significant at 1%; Values were represented as *r* (*p*-value); SN: Sella-nasion distance; SNMP: Sella-nasion mandibular plane angle; MMA: Maxillomandibular plane angle; UISN: Upper incisor sella-nasion angle; UIPP: Upper incisor palatal plane angle.

Table-4: Relationship of sinus index with independent variables.

Parameter	β (S.E)	*t*-stat (*p*-value)
Constant	0.62 (1.14)	0.54 (0.58)
Incisor Class		
Class II Division 1 with contact	-0.01 (0.18)	-0.05 (0.96)
Class II Division 1 without contact	-0.11 (0.19)	-0.57 (0.56)
Class II Division 2	0.56 (0.21)	2.67 (0.008**)
Class III reverse overjet	0.35 (0.18)	1.95 (0.05)
Anterior open bite	0.41 (0.19)	2.12 (0.03*)
SN	0.02 (0.01)	2.27 (0.02*)
SNMP	0.06 (0.02)	3.82 (< 0.001**)
MMA	-0.02 (0.02)	-1.35 (0.17)
UISN	0.02 (0.01)	1.47 (0.14)
UIPP	-0.03 (0.01)	-2.0 (0.04*)

*Significant at 5%; **Significant at 1%. β: Beta, SE: Standard error, SN: Sella-nasion distance, SNMP: Sella-nasion mandibular plane angle, MMA: Maxillomandibular plane angle, UISN: Upper incisor sella-nasion angle, UIPP: Upper incisor palatal plane angle.

Table-2: Patients classification criteria.

Comparison Group	Class I	The lower incisal edges are touching at the cingulum of upper incisors.
Malocclusion Group	Class II division 1 incisors with contact	The lower incisal edges are behind the cingulum of upper incisors having contact on the palate.
	Class II division 1 incisors without contact	The lower incisal edges are behind the cingulum of upper incisors with no contact on the palate.
	Class II division 2 incisors	The upper central incisors are retroclined while the upper lateral incisors are proclined.
	Class III incisors with reverse overjet	The upper incisal edges lie behind the lower incisal edges having no contact with the lower incisors.
	Anterior open bite	There is no vertical contact between upper and lower incisal edges.

Table-2: Mean comparison of sinus index among incisor classes.

Incisor Class	Mean±SD	95 % C. I	*p*-value¥
Class I	2.69±0.6	(2.5, 2.9)	-
Class II Division 1 with contact	2.56±0.4	(2.4, 2.7)	0.96
Class II Division 1 without contact	2.54±0.6	(2.3, 2.7)	0.73
Class II Division 2	3.22[a]**±0.5	(3.0, 3.4)	0.001**
Class III reverse overjet	2.74±0.5	(2.6, 2.9)	0.98
Anterior open bite	3.03[a]* ±0.5	(2.9, 3.2)	0.03*

SD: Standard deviation; CI: Confidence interval; ¥Kruskal-Wallis Test; [a]: Compared with Class I using Pairwise Test; *Significant at 5%; **Significant at 1%.

After adjustment of independent variables, Class II division 2 had 0.56 times (p=0.008) and anterior open bite had 0.41 times (p=0.03) higher median sinus index compared to Class I. Median sinus index levels increased by 0.02 times with SN (p=0.024), 0.06 times with SNMP ($p<0.001$), and decreased by 0.03 times with UIPP (p=0.04) after adjusting for incisor classes as well as MMA and UISN variables (Table 4).

Discussion

The existence of a relationship between craniofacial complex and stomatognathic system calls for better understanding to interpret the internal architecture and bone changes as per the change in function in accordance with the Wolf's law.[13] The more known this relationship is, the better we can implement its in orthodontics. The current study aimed at determining the relationship of anterior occlusion and skeletal variables with FSI.

The results demonstrated that the sinus index was smaller in Class I than all the malocclusion groups, except Class II division 1 with contact and without contact. This finding emphasised the use of three-dimensional (3D) radiography for a more detailed perspective and changes in internal bone architecture.

The smaller FSI in Class I, as depicted in the study, correlated well with the study showing smaller frontal sinus size with Class I incisors than various incisor classes.[8,14] This explains that the harmonious force delivers to the frontal sinus through the anterior dental arch along the medial periphery of orbit, leading to a difference in the size of the frontal sinus.[7]

There was a significant difference in Class II division 2 and anterior open bite groups, whereas there was a non-significant difference in Class III reverse overjet group compared to Class I. The result differed for this group from a previous study[8] which might have been due to the inclusion of the patients with reverse overjet having mandibular incisal contact with the maxillary incisors rather than only including the patients with Class III reverse overjet having no contact between mandibular and maxillary incisors.

The group that demonstrated the highest sinus index value was the Class II division 2 group, followed by the anterior open bite and Class III reverse overjet groups. In the Class II division 2 group, the highest index value might result from aberrant maxillary incisor contact resulting in inadequate force delivery through maxillofacial trajectories, while in the anterior open bite group, the results could be attributed to less transmission of forces due to no contact between maxillary and mandibular teeth, resulting in weaker masticatory muscles.[15,16] The masticatory muscular forces stimulate bone formation directly or indirectly, indicating that there is an inherent link between the distribution of occlusal loads and the shape of the craniofacial skeleton.[17]

Multiple quantile regression analysis showed that Class II division 2 and anterior open bite groups had 0.56 times and 0.041 times higher median sinus index than Class I. Furthermore, the median sinus index level increased by 0.02 times with SN, 0.06 times with SNMP, and decreased by 0.03 times with UIPP, demonstrating the significant effect on the frontal sinus index, with SNMP being more significant than the other variables. These findings correlated well with previous studies, suggesting that these factors have a significant impact on frontal sinus size.[8,14,18] Increase in the thickness of the frontal bone, apposition in the glabella region, and increase in the size of frontal sinus contributes to an increase in the length of the anterior cranial base.[19] The hyper-divergent profile, as indicated by the large SNMP angle leads to the inadequate transmission of forces through the nasal pillars, increasing the frontal sinus size.[8] The finding that there is a decrease in sinus index with the increase in UIPP angle might have resulted due to improper force direction and distribution of occlusal loads to the craniofacial skeleton. This indicates that the patients having a long anterior cranial base or anterior open bite or retroclined maxillary incisors will have a greater sinus index.

The current study used lateral cephalogram, and calculated the sinus index rather than sinus size, as a clinician can easily calculate it without using any software. Furthermore, the sinus index is the ratio that is more reliable than absolute values due to the presence of an inherent shortcoming of 2D cephalometry.[12] The current result differs from other studies[8,20] related to the relationship between anterior dental occlusion and frontal sinus. The reason for the difference might be attributed to methodology as one study used cone beam computed tomography (CBCT), while the other used posteroanterior and lateral cephalogram for frontal sinus size estimation, bearing a small sample size of Class II division 2 and Class III subjects.[8,20]

The current study has limitations owing to the inherent shortcomings of 2D radiography, indicating that 3D radiography should be preferred wherever possible. The stratification on the basis of gender was not done due to a small sample size.

Future studies should consider comparing FSI and frontal sinus size for harmonious anterior dental occlusion.

Conclusions

The FSI can be considered an indicator of harmonious anterior occlusion. The sinus index was greater in Class II division 2 and anterior open bite than in Class I, indicating the Class I incisor group's harmonious force delivery. The sinus index increased with an increase in SN and SNMP, and decreased with an increase in UIPP.

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References

1. Zhao H, Li Y, Xue H, Deng ZH, Liang WB, Zhang L. Morphological analysis of three-dimensionally reconstructed frontal sinuses from Chinese Han population using computed tomography. Int J Legal Med. 2021; 135:1015-23. doi: 10.1007/s00414-020-02443-5.
2. Abate A, Gaffuri F, Lanteri V, Fama A, Ugolini A, Mannina L, et al. A CBCT based analysis of the correlation between volumetric morphology of the frontal sinuses and the facial growth pattern in caucasian subjects. A cross-sectional study. Head Face Med. 2022;18(1):4. doi: 10.1186/s13005-022-00308-3.
3. Celiker M, Kanat A, Ozdemir A, Celiker FB, Kazdal H, Ozdemir B, et al. Controversy about the protective role of volume in the frontal sinus after severe head trauma: larger sinus equates with higher risk of death. Br J Oral Maxillofac Surg. 2020; 58:314-8. doi: 10.1016/j.bjoms. 2019.12.008.
4. Dastan F, Ghaffari H, Shishvan HH, Zareiyan M, Akhlaghian M, Shahab S. Correlation between the upper airway volume and the hyoid bone position, palatal depth, nasal septum deviation, and concha bullosa in different types of malocclusion: A retrospective cone-beam computed tomography study. Dent Med Probl. 2021; 58:509-14. doi: 10.17219/dmp/130099.
5. Preuschoft H, Witte H, Witzel U. Pneumatized spaces, sinuses and spongy bones in the skulls of primates. Anthropol Anz. 2002; 60:67-79.
6. Sawada M, Yamada H, Higashino M, Abe S, Tanaka E. Volumetric Assessment of the Frontal Sinus in Female Adolescents and Its Relationship with Craniofacial Morphology and Orthodontic Treatment: A Pilot Study. Int J Environ Res Public Health. 2022; 19: 7287. doi.10-3390/ijerph19127287. PMID: 35742538; PMCID:PMC 9224355.
7. Witzel U, Preuschoft H. Function-dependent shape characteristics of the human skull. Anthropol Anz. 2002; 60:113-35.
8. Said OT, Rossouw PE, Fishman LS, Feng C. Relationship between anterior occlusion and frontal sinus size. Angle Orthod. 2017; 87:752-8. doi: 10.2319/010617-18.1.
9. Throckmorton GS, Ellis E. The relationship between surgical changes in dentofacial morphology and changes in maximum bite force. J Oral Maxillofac Surg. 2001; 59:620-7. doi: 10.1053/joms.2001.23373.
10. Prado FB, Rossi AC, Freire AR, Groppo FC, De Moraes M, Caria PH. Pharyngeal airway space and frontal and sphenoid sinus changes after maxillomandibular advancement with counterclockwise rotation for Class II anterior open bite malocclusions. Dentomaxillofac Radiol. 2012; 41:103-9. doi: 10.1259/dmfr/ 22419253.
11. Broadbent BH. A new X-ray technique and its application to orthodontia: the introduction of cephalometric radiography. Angle Orthodontist. 1981; 51:93-114.
12. Luo H, Wang J, Zhang S, Mi C. The application of frontal sinus index and frontal sinus area in sex estimation based on lateral cephalograms among Han nationality adults in Xinjiang. J Forensic Leg Med. 2018; 56:1-4. doi: 10.1016/j.jflm.2017.12.014.
13. Frost HM. Wolff's Law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod. 1994; 64:175-88. doi: 10.1043/0003-3219(1994)064<0175:WLABSA> 2.0.CO;2.
14. Yassaei S, Emami A, Mirbeigi S. Cephalometric association of mandibular size/length to the surface area and dimensions of the frontal and maxillary sinuses. Eur J Dent. 2018; 12:253-61. doi: 10.4103/ejd.ejd_345_17.
15. Benington PC, Gardener JE, Hunt NP. Masseter muscle volume measured using ultrasonography and its relationship with facial morphology. Eur J Orthod. 1999; 21:659-70. doi: 10.1093/ejo/ 21.6.659.
16. Havner C, Roussakis A, Sjögreen L, Westerlund A. Open bite malocclusion and orofacial dysfunction in patients with myotonic dystrophy type 1 and Duchenne muscular dystrophy. J Neuromuscul Dis. 2023; 10:885-96. doi: 10.3233/JND-230025.
17. Mavropoulos A, Kiliaridis S, Bresin A, Ammann P. Effect of different masticatory functional and mechanical demands on the structural adaptation of the mandibular alveolar bone in young growing rats. Bone. 2004; 35:191-7. Bone. 2004; 35:191-7.
18. Tehranchi A, Motamedian SR, Saedi S, Kabiri S, Shidfar S. Correlation between frontal sinus dimensions and cephalometric indices: A cross-sectional study. Eur J Dent. 2017; 11:64-70. doi: 10.4103/1305-7456.202630.
19. Knott VB. Change in cranial base measures of human males and females from age 6 years to early adulthood. Growth. 1971; 35:145-58.
20. Dah-Jouonzo H, Baron P, Faure J. [Correlations between the volume of the sinuses and the facial bones and parameters of 3D cephalometry]. Orthod Fr. 2007; 78:265-81. doi: 10.1051/orthodfr: 2007030.

Author Contribution:

TA: Study design, data collection and entry, writing and revision.

SR: Study design, data collection, revision and writing.

IA: Study design, revision and final approval.

WAF: Sample size calculation, statistical analysis and data interpretation.