

# Dimensional Analysis of Frontal Sinus in Various Skeletal Malocclusions

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## ABSTRACT

**Introduction:** Growth and development of paranasal sinuses affect different orthodontic malocclusions playing an important role in the formation of facial anatomy.

**Objective:** To compare the dimensions of frontal sinus among different skeletal relations, gender groups and to analyse the relationship between length of the mandible and frontal sinus dimensions.

**Materials and Method:** An analytical cross-sectional study was conducted during April-September 2020 at Kantipur Dental College. The sample consisted of 195 lateral cephalograms with 65 samples each in three different skeletal malocclusion groups of Nepali individuals. The subjects with paranasal sinus pathology and history of previous orthodontic treatment were excluded. The samples were manually traced and analysed by measuring maximum width, maximum height, area of frontal sinus, and length of the mandible. One-way analysis of variance test was performed followed by post hoc test to compare the difference between skeletal classes. Independent t-test was done to compare the gender difference at  $P < 0.05$ .

**Result:** Statistically significant differences were observed in maximum width, area of frontal sinus and length of mandible with respect to skeletal malocclusions. The frontal sinus area was largest in Class III and smallest in Class II group. Significant difference was observed in frontal sinus measurements between the gender groups.

**Conclusion:** Frontal sinus area was found to be the largest in Class III and smallest in Class II. These variations in the measurements of frontal sinus should be considered in diagnosis and treatment planning of orthodontic and orthognathic cases.

**Keywords:** Frontal sinus; lateral cephalometry; skeletal pattern.

## INTRODUCTION

Growth and development of frontal sinus can have effect on the development of different skeletal malocclusions. Frontal sinus can be featured in the lateral cephalogram. Anatomical landmarks of frontal sinus can be the supplementary diagnostic parameters in orthodontics and orthognathic surgery.<sup>1,2</sup>

Rossouw et al. suggested frontal sinus as a predictor of mandibular growth pattern and found frontal sinus

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larger in Class III group.<sup>3</sup> Prashar et al. associated larger frontal sinus with large mandible irrespective of their positional relationships.<sup>4</sup> Paranasal sinuses follow same growth pattern as in bone growth. Peculiar characteristics of frontal sinus in terms of size, shape, and position has made the frontal bone anatomically unique.<sup>5,6</sup> Frontal sinus is resistant to trauma and is likely to be preserved after mass disasters. The shape of the frontal sinus is affected by gender, race, disease, environmental factors, and growth.<sup>7</sup>

The literature relating to frontal sinus show very few studies. Thus, the purpose of this study was to compare the dimensions of the frontal sinus in various skeletal malocclusions, assess the difference and analyse the relationship between the length of the mandible and frontal sinus dimension in patients visiting Kantipur Dental College Teaching Hospital.

## MATERIALS AND METHOD

An analytical cross-sectional study was conducted at the Department of Orthodontics, Kantipur Dental College Teaching Hospital, Kathmandu. The study was approved by Institutional Review Committee (Ref. 13/2020) and was conducted during April-September 2020. Sample size was calculated using the data from the study of Acharya et al.<sup>8</sup> in following formula:

$$\text{Sample Size}(n) = \frac{z^2pq}{e^2} \left[ 1 + \frac{z^2pq}{e^2N} \right]$$

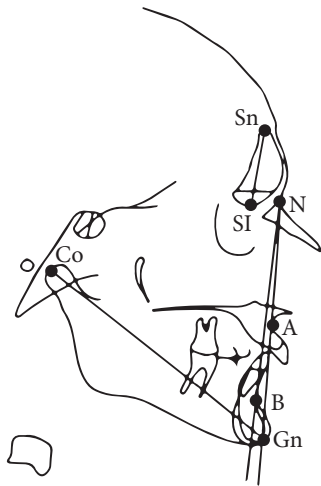
Where,  $z=1.96$ ,  $p=0.793$  (79.3%),  $q=1-p=0.207$ ,  $e=0.05$  (5%),  $N=87$  (number of new patients visiting the department in a period of last six months). Thus, the sample size was calculated to be 65 for each category. The samples were selected using the secondary data from the Department of Orthodontics at Kantipur Dental College Teaching Hospital, Kathmandu. The total sample consisted of 195 lateral cephalograms with 65 samples each in three different skeletal malocclusion groups of Nepali individuals. The samples were selected between the age range of 16-30 years with the ANB value between  $2 \pm 2^\circ$  for Class I,  $>4^\circ$  for Class II and  $<0^\circ$  for Class III. The participants with any paranasal sinus pathology, congenital disease, trauma, and

history of previous orthodontic treatment were excluded.

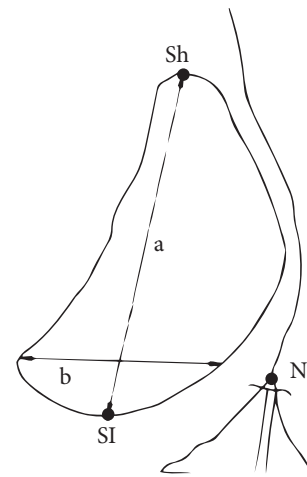
The cephalograms were traced manually<sup>9</sup> by a single investigator with 0.5 mm 2B lead pencil using a millimetre scale on acetate tracing paper. Cephalometric points were located and linear measurements were measured. The frontal sinus area was calculated by superimposing the frontal sinus drawn on acetate paper over a standard graph paper sheet. The number of squares present within the inner outline of frontal sinus was counted and measured as square millimetres. It was only counted as full square when more than half area of the square was within the perimeter of the frontal sinus.<sup>10</sup>

Twenty percent of the total samples were selected and traced after seven days from the initial measurement. Kappa test showed substantial intraobserver agreement for all measurements as kappa value for each measurement was above 0.75. Statistical analysis was done using IBM SPSS Statistics for Windows, version 21 (IBM Corp., Armonk, N.Y., USA). Data was normally distributed as checked with Kolmogorov-Smirnov test. One-way analysis of variance (ANOVA) test followed by post hoc test was performed. Bonferroni and Sidak tests were performed to assess the difference in frontal sinus dimensions among different groups of malocclusions. Statistical level was set at  $P < 0.05$  for significance. Following cephalometric points and linear measurements were used.

Point A (A): The deepest midline point on the premaxilla between the anterior nasal spine and prosthion, Point B (B): The most posterior point in the concavity between the infradentale and pogonion, Nasion (N): The anterior limit of the frontonasal suture, Condylion (Co): The most posterior and superior point on the condyle of the mandible and Gnathion (Gn): The most anterior and inferior point on the symphysis of mandible (Figure 1). Co-Gn: The effective length of the mandible (Figure 1), Maximum height of frontal sinus: A line connecting Sh (Point Sh, most highest point on the peripheral border of the frontal sinus) to Sl (Point Sl, most lowest point on the peripheral border of the of frontal sinus) is drawn to measure the maximum height of frontal sinus and width of frontal sinus: Perpendicular to above line, a line was drawn to measure the maximal width of frontal sinus (Figure 2).



**Figure 1: Cephalometric tracing depicting landmarks: 1. Nasion (N) 2. Point A (A) 3. Point B (B) 4. Point Sh (Sh) 5. Point SI (SI) 6. Condylion (Co).**



**Figure 2: Cephalometric tracing depicting landmarks of frontal sinus: 1. Nasion (N) 2. Point Sh (Sh) 3. Point SI (SI) 4. Maximum height (a) 5. Maximum width (b).**

## RESULT

The sample consisted of 195 lateral cephalograms of the subjects aged between 16 to 30 years. Descriptive statistics of linear dimensions for skeletal classes are given in Table 1.

Mean values of maximum height of frontal sinus in Class I, Class II, and Class III malocclusion were 22.35 mm, 20.31 mm, and 21 mm, respectively. Mean values of maximum width of frontal sinus in

Class I, Class II, and Class III malocclusions were 9.26 mm, 8.65 mm, and 10.08 mm respectively. Mean value of area of frontal sinus in Class I, Class II, and Class III malocclusions were 174.91 mm, 133.92 mm and 184.09 mm respectively. Mean values of length of mandible in Class I, Class II, and Class III malocclusion were 112.32 mm, 104.69 mm, and 114.55 mm respectively (Table1). The results of comparison between gender groups using t-test are given in Table 2.

**Table 1: Descriptive statistics of linear dimensions for skeletal classes.**

Skeletal malocclusion	Parameter	Mean±SD
Class I	Maximum height (mm)	22.35±0.86
	Maximum width (mm)	9.26±0.43
	Frontal sinus area (mm <sup>2</sup> )	174.91±9.83
	Length of mandible (mm)	112.32±1.47
Class II	Maximum height (mm)	20.31±0.89
	Maximum width (mm)	8.65±0.33
	Frontal sinus area (mm <sup>2</sup> )	133.92±8.31
	Length of mandible (mm)	104.69±1.52
Class III	Maximum height (mm)	21±0.81
	Maximum width (mm)	10.08±0.36
	Frontal sinus area (mm <sup>2</sup> )	184.09±9.61
	Length of mandible (mm)	114.55±1.28

**Table 2: Comparison between gender groups using t-test.**

Parameter	Gender	Mean±SD	P value
Maximum height (mm)	Male	22.44±7.30	0.022
	Female	20.17±6.45	
Maximum width (mm)	Male	10.32±2.82	<0.001
	Female	8.48±3.08	
Frontal sinus area (mm <sup>2</sup> )	Male	176.88±80.33	0.030
	Female	153.53±73.80	
Length of mandible (mm)	Male	47.63±5.61	0.240
	Female	46.50±7.54	

**Table 3: Comparison among skeletal classes for linear dimensions using ANOVA.**

Parameter		Sum of squares	df	Mean square	F	P value
Maximum height	Between groups	140.810	2	70.405	1.471	0.232
	Within groups	9190.708	192	47.868		
	Total	9331.518	194	-		
Maximum width	Between groups	66.964	2	33.482	3.575	0.030
	Within groups	1798.031	192	9.365		
	Total	1864.995	194	-		
Frontal sinus area	Between groups	92756.031	2	46378.015	8.287	<0.001
	Within groups	1074573.508	192	5596.737		
	Total	1167329.538	194	-		
Length of mandible	Between groups	3476.523	2	1738.262	13.131	<0.001
	Within groups	25416.123	192	132.376		
	Total	28892.646	194	-		

Mean values of maximum height and width of frontal sinus in male and female were 22.44 mm and 20.17 mm and 10.32 mm, and 8.48 mm respectively. Mean values of area of frontal sinus and length of mandible in male and female were 176.88 mm and 153.53 mm and 47.63 mm and 46.50 mm respectively. The difference was statistically significant for maximum height, maximum width

and area of frontal sinus in male and female (Table 2). The results of comparison among skeletal classes for linear dimensions using ANOVA are given in Table 3. ANOVA showed that the difference in maximum width, area of frontal sinus and length of the mandible were statistically significant among the skeletal classes (Table 3). Table 4 depicts post hoc test (Bonferroni and Sidak methods) for multiple comparisons of malocclusions.

**Table 4: Bonferroni and sidak methods for post hoc analysis.**

Parameter	Test	(I) Class	(J) Class	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
							Lower bound	Upper bound
Maximum height	Bonferroni	Class I	Class II	2.046	1.214	0.280	-0.88	4.98
			Class III	1.354	1.214	0.798	-1.58	4.28
		Class II	Class I	-2.046	1.214	0.280	-4.98	0.88
			Class III	-0.692	1.214	1.000	-3.62	2.24
		Class III	Class I	-1.354	1.214	0.798	-4.28	1.58
			Class II	0.692	1.214	1.000	-2.24	3.62
	Sidak	Class I	Class II	2.046	1.214	0.255	-0.88	4.97
			Class III	1.354	1.214	0.605	-1.57	4.28
		Class II	Class I	-2.046	1.214	0.255	-4.97	0.88
			Class III	-0.692	1.214	0.920	-3.62	2.23
		Class III	Class I	-1.354	1.214	0.605	-4.28	1.57
			Class II	0.692	1.214	0.920	-2.23	3.62
Maximum width	Bonferroni	Class I	Class II	0.615	0.537	0.759	-0.68	1.91
			Class III	-0.815	0.537	0.391	-2.11	0.48
		Class II	Class I	-0.615	0.537	0.759	-1.91	0.68
			Class III	-1.431	0.537	0.025	-2.73	-0.13
		Class III	Class I	0.815	0.537	0.391	-0.48	2.11
			Class II	1.431	0.537	0.025	0.13	2.73
	Sidak	Class I	Class II	0.615	0.537	0.583	-0.68	1.91
			Class III	-0.815	0.537	0.342	-2.11	0.48
		Class II	Class I	-0.615	0.537	0.583	-1.91	0.68
			Class III	-1.431	0.537	0.025	-2.72	-0.14
		Class III	Class I	0.815	0.537	0.342	-0.48	2.11
			Class II	1.431	0.537	0.025	0.14	2.72

Parameter	Test	(I) Class	(J) Class	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
							Lower bound	Upper bound
Frontal sinus area	Bonferroni	Class I	Class II	40.985	13.123	0.006	9.29	72.68
			Class III	-9.185	13.123	1.000	-40.88	22.51
		Class II	Class I	-40.985	13.123	0.006	-72.68	-9.29
			Class III	-50.169	13.123	0.001	-81.86	-18.48
		Class III	Class I	9.185	13.123	1.000	-22.51	40.88
			Class II	50.169	13.123	0.001	18.48	81.86
	Sidak	Class I	Class II	40.985	13.123	0.006	9.38	72.59
			Class III	-9.185	13.123	0.863	-40.79	22.42
		Class II	Class I	-40.985	13.123	0.006	-72.59	-9.38
			Class III	-50.169	13.123	0.001	-81.78	-18.56
		Class III	Class I	9.185	13.123	0.863	-22.42	40.79
			Class II	50.169	13.123	0.001	18.56	81.78
Length of mandible	Bonferroni	Class I	Class II	7.631	2.018	0.001	2.76	12.50
			Class III	-2.231	2.018	0.811	-7.10	2.64
		Class II	Class I	-7.631	2.018	0.001	-12.50	-2.76
			Class III	-9.862	2.018	0.000	-14.74	-4.99
		Class III	Class I	2.231	2.018	0.811	-2.64	7.10
			Class II	9.862	2.018	<0.001	4.99	14.74
	Sidak	Class I	Class II	7.631	2.018	0.001	2.77	12.49
			Class III	-2.231	2.018	0.612	-7.09	2.63
		Class II	Class I	-7.631	2.018	0.001	-12.49	-2.77
			Class III	-9.862	2.018	<0.001	-14.72	-5.00
		Class III	Class I	2.231	2.018	0.612	-2.63	7.09
			Class II	9.862	2.018	<0.001	5.00	14.72

## DISCUSSION

In the present study, there was statistically significant difference in the maximum width and area of the frontal sinus region in skeletal Class I, Class II, and Class III malocclusion. The frontal sinus area is found to be largest in Class III and smallest in Class II which is in accordance with the study done by Ahuja et al.,<sup>11</sup> Sabaharwal et al.,<sup>10</sup> Prashar et al.,<sup>4</sup> Rossouw et al.,<sup>3</sup> Joffe et al.,<sup>12</sup> and Dhiman et al.<sup>13</sup> However, the study conducted by Kapasiawala et al.<sup>14</sup> observed no significant difference among maximum height, width, and area of frontal sinus with respect to Class I, Class II, and Class III.

The effective length of the mandible (Co-Gn) was significantly greater with respect to different skeletal class which was greatest in Class III and shortest in Class II. No statistically significant difference was observed in the maximum height of the frontal sinus in different skeletal class which was in accordance with Kapasiawala et al.<sup>14</sup>

Statistically significant difference was observed in the maximum height, maximum width and area of frontal sinus while statistically insignificant differences was observed in the effective length of the mandible among male and female groups. It was found that the maximum height, width and area of the frontal sinus were greater in male as compared to female. Statistically significant differences were observed in the frontal sinus measurements between male and female which was in accordance with Chennoju et al.<sup>15</sup> supporting the dimorphic features of frontal sinus in humans.

Skeletal class parameter (ANB) is found to be negatively correlated with area of the frontal sinus measurement and effective length of the mandible which was in accordance with Rossouw et al.<sup>3</sup> Frontal sinus width showed highly significant correlation with mandibular base length in Class III subjects which enables frontal sinus to serve as an indicator for the presence of skeletal jaw discrepancy.<sup>16</sup> The development of the frontal sinus

have been interpreted as a process of structural adaptation to the forward and downward growth of the midface with the forward growth of the external lamina of the frontal bone being essential to keep the contact with the nasal bone and maxilla.<sup>17</sup> While such an explanation is acceptable for Class II cases, it cannot be applied for Class III cases. Increase in frontal sinus size follows the same general body growth curve during puberty.<sup>18,19</sup>

Maximum mean value of the width of the frontal sinus was recorded in Class III followed by Class I and Class II. Al-Bustani<sup>16</sup> reported that frontal sinus width significantly correlated with maxillary denture base in Class II and mandibular base length in Class III. Increased frontal sinus width in skeletal Class III malocclusion was reported in various studies and proposed to be associated with excessive mandibular growth.<sup>3,12,18-22</sup> The factors contributing to sinus enlargement have not been completely understood which are individual differences in the growth and resorption processes of the mucosa, quality of frontal bone which is to be pneumatized, pressure of the growing brain on the internal lamina of the area of frontal sinus, various pressure and hydrodynamic conditions of the endocranium affecting the blood supply of the frontal sinus area, hereditary and hormonal factors. Assessment of frontal sinus dimension is significant in diagnosis and treatment planning. Hence, it is essential for an orthodontist to be acquainted with usual growth and development pattern of the frontal sinus.

The study was conducted among the patients visiting Kantipur Dental College Teaching Hospital

which cannot represent the wider population group and based on lateral cephalogram which is a two-dimensional representation of three-dimensional structure. The use of cephalogram in assessing frontal sinus is of paramount importance since newer diagnostic aids like cone beam computed tomography are technique sensitive and costly to perform in every case especially in developing countries.

## CONCLUSION

Statistically significant differences were observed in the maximum width, area of the frontal sinus, and length of the mandible with respect to skeletal malocclusions. The frontal sinus area and width was found to be largest in Class III and smallest in Class II. Significant difference was observed in the frontal sinus measurements between the gender groups. Frontal sinus can serve as an additional diagnostic indicator, enabling the orthodontist to make more accurate prediction and diagnosis for the skeletal jaw growth pattern.

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