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Assessment of Dentofacial Characteristics and Pharyngeal Airway in Children with Class II Malocclusion and Mouth Breathing

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Abstract

Background In growing patients with skeletal discrepancies, early diagnosis, evidence-based explanation of etiology, and assessment of functional factors can be vital for the restoration of normal craniofacial growth and the stability of treatment needs.

Aims The aim of the study was to assess dentofacial characteristics as well as upper and lower pharyngeal airway in children with skeletal class II malocclusion with mouth breathing, and to investigate possible significant relationships and correlations among the studied cephalometric variables and the airway morphology in these children.

Materials and Methods Sixty untreated children, aged 9 to 13 years, were divided into three groups according to clinical findings and cephalometric analysis of dentofacial characteristics as well as the presence of mouth breathing habit: Group I (20 children with normal jaw relation/class I), Group II (20 children with skeletal class II), and Group III (20 children with skeletal class II with confirmed mouth breathing habit). Cephalometric variables and upper/lower airway widths were recorded. Intergroup comparison of all measurements was performed by post hoc Tukey test, and Pearson's correlation was used to determine the correlation among the variables.

Results Significant changes existed in more than half of the dentofacial measurements among the three groups. Significantly greater skeletal anteroposterior jaw discrepancy and mandibular retrognathism were found in both groups II and III as determined by specific anteroposterior determinants. Children in group III showed significantly increased angle between Sella-Nasion and mandibular plane (SN-MP) angle, *y*-axis, and a vertical growth pattern. Significant increases in dental measurements, namely upper incisor to Nasion- point A (NA), lower incisor to Nasion - point B (NB), and overjet, were found in group II and group III, while overbite showed a significant decrease. Upper pharyngeal airway width was found to be significantly decreased in group III followed by a smaller though significant decrease in group II. No significant differences were found in lower pharyngeal airway width between the

Keywords
- mouth breathing
- skeletal class II malocclusion
- pharyngeal airway

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groups. There were statistically significant dentofacial characteristics that showed fair to good correlation with the upper airway width.

Conclusion Children with skeletal class II malocclusion with and without mouth breathing showed significant differences in dentofacial measurements and a significantly narrower upper pharyngeal airway as compared with children with normal jaw/class I relation.

Introduction

During the course of growth period, diverse etiologic features like dentoalveolar development, maxillary and mandibular growth, tongue and lips functions, and eruption of the teeth may cause malocclusion. The features in sagittal malocclusions are proclination of incisors, short and hypotonic upper lip, and incompetent lips with convex profile.[1]

Correct muscle activity stimulates proper facial growth and bone development when nose breathing is combined with regular eating and swallowing processes, as well as posture of the tongue and lips.[2] However, depending on the severity, duration, and time of occurrence, dysfunctions such as nasorespiratory blockage can affect dentofacial morphology.[3] Ricketts observed that the key features of the respiratory obstruction syndrome are presence of hypertrophied tonsils or adenoids, mouth breathing, open bite, cross bite, and narrow external nares.[4] Mouth breathing can cause postural changes such as the mandible being lowered, the head being lifted, the hyoid bone being lowered, and the tongue becoming anterior inferior.[2,3]

Mouth breathing has also been shown to alter the lower third face, mandibular rotation, and excessive mandibular angle in studies. Nasal obstruction affects muscular function, which can lead to dentofacial abnormalities.[5,6]

The size of the pharyngeal space is mostly influenced by the growth and size of the soft tissues that surround the dentofacial skeleton.[7] Reduced pharyngeal airway passage can be caused by cranial anomalies such as mandibular or maxillary retrognathism, small mandibular body, and backward and downward rotation of the jaw.[8] Reduced space between the mandibular corpus and the cervical column may cause posterior changes in tongue and soft palate posture, impair respiratory function during the day, and possibly cause nocturnal problems such as snoring, upper airway resistance syndrome, and obstructive sleep apnea.[9]

The occlusion of the upper and lower pharyngeal airways, as well as mouth breathing, is linked to vertical growth pattern. Vertical growth patterns and class II malocclusions are necessary to indicate anatomic predisposing factors if this association exists.[10] Early diagnosis, evidence-based explanation of etiology, and assessment of functional aspects may be critical for the restoration of normal craniofacial growth and stability of treatment needs in growing patients with skeletal discrepancies and clinical symptoms of adenoid facies.[11–13]

The aim of this prospective cross-sectional clinical investigation was to compare dentofacial features and pharyngeal airway in children with skeletal class II malocclusion with or without mouth breathing habit to healthy children with normal craniofacial relationship. Any significant correlations between the various cephalometric characteristics and the airway morphology of the children were also examined.

Materials and Methods

The Research Ethics Committee of our Institution approved the study (Cert. No. ABSM/EC/2011), which was in accordance with the 1964 Helsinki declaration and its later amendments. Informed written consent from the parents and oral assent from the participating children were obtained.

Source of Data

Data source comprised of children aged 9 to 13 years with normal skeletal jaw relation (class I) and untreated class II malocclusion reporting to the Outpatient Department of Pediatric and Preventive Dentistry of our Institution. The selected children required interceptive orthodontic therapy and therefore needed radiographic investigation.

Experimental Design

Sample Size Estimation

Based on the expected difference in the airway volume, the sample size estimation is done.

$Sp = 1{,}836$

Mean difference $= 2{,}027$

z value of $æ$ – $5\% = 1.96$

z value of β – $20\% = 0.84$

$n = 2(1.96 + 0.84)^{2*}(1{,}836)/(2{,}027)^2$

$= 12.86$, which is rounded off to 20 per group.

The sample size was estimated using the formula:

$n = 2s_p{}^2[Z_{1-\alpha/2} + Z_{1-\beta}]^2$

$\mu^2{}_d$

$S^2{}_p = S^2{}_1 + S^2{}_2$

2

Where,

$S^2{}_1$: Standard deviation in the first group

$S^2{}_2$: Standard deviation in the second group

α: Significance level

$1–\beta$: Power

Sixty children were thus selected and grouped as follows:

Group 1: 20 children clinically and radiographically diagnosed with class I molar relation bilaterally and class I skeletal relationship, served as the control group.

Group 2: 20 children clinically and radiographically diagnosed with skeletal class II malocclusion.

Group 3: 20 children clinically and radiographically diagnosed with skeletal class II malocclusion and with confirmed mouth breathing habit.

The presence of mouth breathing was confirmed by standardized tests.[14–16]

Eligibility Criteria

1 Children with normal skeletal class I jaw relation (difference between SNA and SNB (ANB) angle between 0° and 3°).

2 Children with untreated skeletal class II division I malocclusion (ANB > 5°) and point of contact on the occlusal plane from A (AO) ahead of point of contact on the occlusal plane from B (BO) (>1 mm).

3 Children with untreated skeletal class II division I malocclusion (ANB > 5°) and AO ahead of BO (>1 mm) with confirmed mouth breathing habit.

Anteroposterior jaw relationship (ANB angle, ►**Fig. 1**) was corroborated by the Wits appraisal.

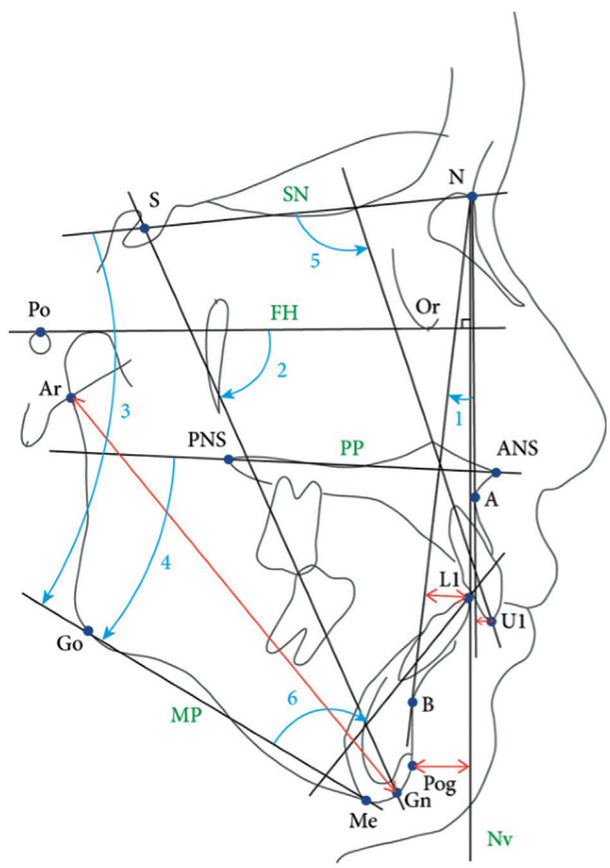

Fig. 1 Cephalometric tracing of angular measurements. Cephalometric landmarks and reference planes for angular measurements: (1) SNA, (2) SNB, (3) ANB, (4) gonial angle, (5) articular angle, (6) saddle angle, (7) upper incisor to NA, (8) lower incisor to NB, (9) upper incisor to SN, (10) upper incisor to palatal plane, (11) lower incisor to mandibular plane, (12) interincisal angle, (13) SN-MP, (14) mandibular plane to palatal plane, (15) occlusal to mandibular plane angle, and (16) (N-S-Gn) Y-axis. Abbreviations: ANB, difference between SNA and SNB; NA, Nasion - point A; NB, Nasion - point B; SN, Sella - Nasion; SNA, Sella - Nasion - point A; SNB, Sella - Nasion - point B; SN-MP, Sella Nasion- Mandibular plane angle.

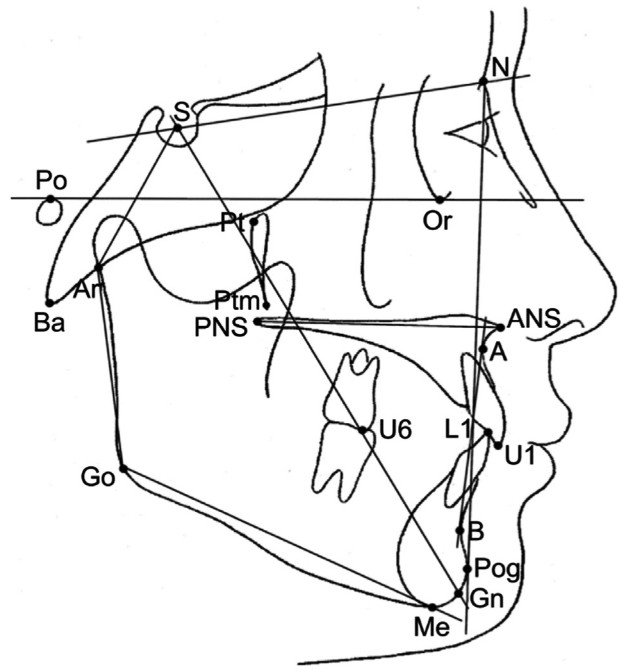

Fig. 2 Cephalometric tracing of linear measurements. Cephalometric landmarks and reference planes for linear measurements: (1) anterior facial height, (2) posterior facial height, (3) facial height ratio, (4) length of maxillary base, (5) length of mandibular base, (6) SN, (7) point A to Nasion perpendicular, (8) PoG to N perpendicular, (9) sella to articulare, (10) articulare to gonial angle, (11) gonial angle to gnathion, (12) nasion to gonial angle, (13) sella to gnathion, (14) overjet, and (15) overbite. Abbreviations: PoG, Pogonion; SN, Sella-Nasion.

Exclusion Criteria

1 No symptoms of upper respiratory and any other pharyngeal pathology including enlarged adenoids.

2 No previous surgery of palatine or pharyngeal tonsils.

Lateral cephalograms were obtained under standardized conditions.[17] All subjects were positioned in the cephalostat with the sagittal plane at a right angle to the path of X-rays. The Frankfort plane was parallel to the horizontal plane, the teeth were in centric occlusion, and lips were lightly closed.

All radiographs were manually traced with a 2H lead pencil on 0.003 inch acetate paper, and the following angular and linear measurements were recorded by a single investigator and double-checked by other investigators for proper landmark identification. Each patient in our study had a total of 31 cephalometric measurements, 16 of which were angular and 15 of which were linear[18] (►**Figs. 1** and **2**). McNamara analysis was used to determine upper and lower airway width[19] (►**Fig. 3**).

Statistical Analysis

All statistical analyses were performed using the *Statistical Package for the Social Sciences*, version 20.0. Arithmetic mean and standard deviation values were calculated for each measurement. For multiple comparisons, one-way analysis of variance and a post hoc Tukey honestly significant

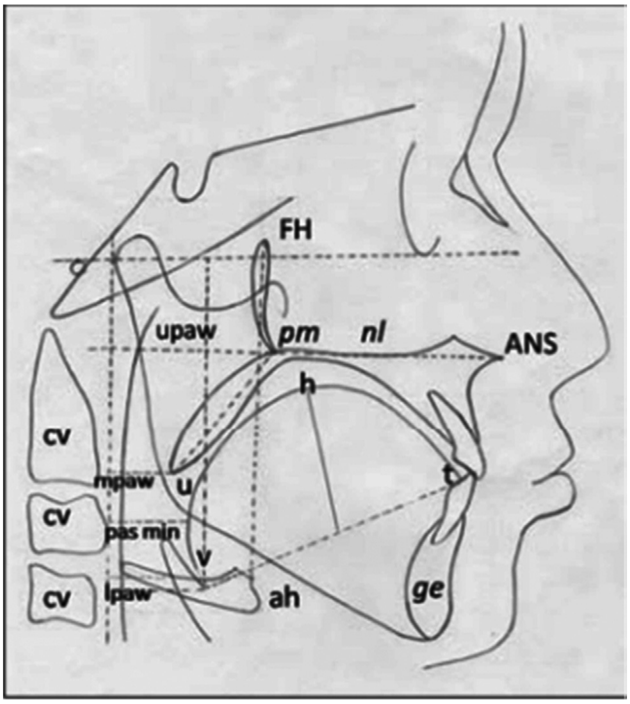

Fig. 3 Cephalometric measurements for airway. (1) McNamara's upper pharynx dimension (PM-UPAW: minimum distance between the upper soft palate and the nearest point on the posterior pharynx wall). (2) McNamara's lower pharynx dimension (U-MPAW: minimum distance between the point where the posterior tongue contour crosses the mandible and the nearest point on the posterior pharynx wall). Abbreviations: PM-UPAW, Pterygomaxillare-upper pharyngeal airway; U-MPAW, Uvula - middle pharyngeal airway.

difference (HSD) test was used. Pearson's correlation was done to correlate the significant variables with airway width. When the p-value was less than 0.05, it was considered to be significant.

Results

A total of 60 children were included in this study. The mean age of the children was 11 ± 1.44 years, while the gender distribution was 33 boys and 27 girls. Intergroup comparison of age and gender revealed that there were statistically no significant differences between the groups.

When angular measurements in groups II and III were compared with those in group I, we found statistically significant differences in the following measurements: Sella - Nasion- point B (SNB) ANB, lower gonial angle, saddle angle, interincisal angle, mandibular plane to palatal plane angle, y-axis ($p < 0.001$, ►**Table 1**), mandibular plane angle, occlusal plane to mandibular plane angle, upper incisor to NA, and lower incisor to NB ($p < 0.05$, ►**Table 1**).

When linear measurements between group II and group III were compared and analyzed with group I, we found statistically significant differences in the Jarabak's ratio, N-Go, overjet, and overbite ($p < 0.001$, ►**Table 2**).

In the present study, children in group I recorded a mean upper airway measurement of 16.25 ± 2.573 mm, which was within normal range values. Intergroup comparison revealed statistically significant differences in upper pharyngeal airway widths among the three groups. Upper pharyngeal airway width was found to be significantly decreased in group III (mean $= 9.85 \pm 1.785$ mm, $p < 0.001$, ►**Table 3**) followed by group II (mean $= 11.05 \pm 2.012$ mm, $p < 0.001$, ►**Table 3**).

Children in group I recorded a mean lower airway measurement of 9.8 ± 1.399 mm, which was within normal range values. However, there were no statistically significant differences in lower pharyngeal airway widths across the groups in our study, and there were no correlations between lower pharyngeal airway width space and craniofacial growth pattern or malocclusion types.

Post hoc Tukey HSD analysis of the intergroup comparison of the results revealed significant differences between groups II and III in certain dentofacial measurements such as upper and lower gonial angles and saddle angle (major angles); vertical measurements such as mandibular plane to palatal plane and y-axis; and dental measurements such as overbite, overjet, and lower incisor to NB and Mandibulae plane (MP) (►**Table 4**).

When correlations among dentofacial variables and upper airway were analyzed in children of group II, we observed that the variables like upper incisor to NA, lower incisor to NB, lower incisor to MP, overbite, and interincisal angle showed a fair to good correlation with upper airway width (►**Table 5**).

When correlations among dentofacial variables and upper airway were analyzed in children of group III, ANB, as length of ramus (ar – Go) angle, upper incisor to palatal plane, overjet, and overbite showed a good correlation with upper airway width (►**Table 6**). However, we found a fair correlation between SN-MP and Nasion – gonion (N-Go) measurements with the upper pharyngeal airway width (►**Table 6**).

Discussion

The growth and function of the nasal cavities, nasopharynx, and oropharynx are all tightly linked to appropriate skull growth. Several studies have found a link between pharyngeal structures and dentofacial and craniofacial structures in both adults and children.[20,21]

It has also been discovered that certain dentofacial features and morphological changes are linked to postural modifications.[22] Because of a possible link between upper airway size and structure and sleep-induced breathing difficulties, attention has recently been drawn to uvulo-glosso-pharyngeal dimensions. Obstructive sleep apnea sufferers have abnormal skeletal and soft tissue patterns that restrict airway space, according to research.[23,24]

We chose children aged 9 to 13 years for our study because these preadolescents have the best chance of receiving early diagnosis and timely care.

The ANB angle was used to determine the anteroposterior skeletal jaw relationship in our investigation, and the Wits appraisal confirmed it. Rotation and vertical growth of the jaws, anteroposterior position of the nasion, and vertical distance between points A and B are all factors that influence

Table 1 Intergroup comparison of various angular dentofacial measurements

	Group I	Group II	Group III	Statistical significance (*p*-Value)	
				Groups I–II	Groups I–III
SNA	82.85	82.9	83.15	0.998	0.928
SNB	80.65	77	77.2	<0.001	<0.001
ANB	2.2	5.85	6	<0.001	<0.001
Upper gonial angle	54.95	51.95	58.15	0.117	0.089
Lower gonial angle	76	69.55	78.75	<0.001	0.065
Articular angle	144.7	148.45	144.6	0.092	0.998
Saddle angle	119.95	121.05	126.3	0.775	<0.001
Upper incisor to NA (angular)	28.2	31.7	32.6	0.025	0.004
Upper incisor to NA (linear)	5.2	5.45	6.9	0.933	0.05
Lower incisor to NB (angular)	27.2	34.3	30.45	<0.001	0.009
Lower incisor to NB (linear)	5.7	5.5	5.9	0.952	0.952
Upper incisor to SN	112	111.1	112.2	0.865	0.993
Upper incisor to palatal plane	65.9	68.6	69.85	0.428	0.169
Lower incisor to mandibular plane	100.45	108.3	100.05	0.002	0.982
Interincisal angle	124.65	119.85	113.45	0.135	<0.001
SN-MP	33.8	34.6	39.8	0.928	0.021
Mandibular plane to palatal plane	34.25	25.1	33.15	<0.001	0.572
Occlusal to mandibular plane angle	16.6	13.5	20.2	0.055	0.022
Y-axis	64.4	64.9		0.859	<0.001

Abbreviations: ANB, difference between SNA and SNB; NA, Nasion - point A; NB, Nasion - point B; SN, Sella - Nasion; SNA, Sella - Nasion - point A; SNB, Sella - Nasion - point B; SN-MP, Sella Nasion- Mandibular plane angle.
Note: Statistically significant differences in the following dentofacial measurements: $p < 0.001$ = highly significant; $p < 0.05$ = significant.

Table 2 Intergroup comparison of various linear measurements

	Group I	Group II	Group III	Statistical significance (*p*-Value)	
				Groups I–II	Groups I–III
Jarabak's ratio	0.639	0.71	0.5955	<0.001	<0.001
Length of maxillary base	52.25	51.8	53.15	0.956	0.835
Length of mandibular base	67.55	70.1	69.25	0.217	0.501
SN	71.1	72.7	71.2	0.343	0.996
Point A to Nasion perpendicular	1.45	3.32	4.73	0.005	<0.001
PoG to N perpendicular	–2.1	–1.9	–5.31	0.965	<0.001
Sella to articulare	36.15	36.2	32.65	0.998	0.001
Articulare to gonial angle	42.25	46.65	43.5	0.002	0.563
Gonial angle to gnathion	70.95	68.6	67.05	0.223	0.02
Nasion to gonial angle	107.75	116.95	109.5	0.364	<0.001
Sella to gnathion	117.3	118.3	112.9	0.85	0.052
Overjet	3.1	3.75	7.95	0.425	<0.001
Overbite	2.4	4.3	1.45	0.001	0.12

Abbreviations: PoG, pogonion; SN, Sella - Nasion.
Note: $p < 0.001$ = highly significant; $p < 0.05$ = significant.

Table 3 Comparison of upper and lower airway width between three groups

	Upper airway			Lower airway		
	N	Mean (mm)	Standard deviation	*N*	Mean (mm)	Standard deviation
Group I	20	16.25	2.573	20	9.8	1.399
Group II	20	11.05	2.012	20	9.65	1.309
Group III	20	9.85	1.785	20	9.05	1.05

the ANB angle, according to Hussels and Nanda.[25] The ANB angle, on the other hand, has been described by Oktay[26] and Ishikawa et al[27] as one of the most trustworthy and accurate assessments of the anteroposterior jaw relationship. As the ANB angle is a popular cephalometric parameter in clinical orthodontics, it was used to categorize the children in our study.[2]

Our findings revealed substantial variations in numerous dentofacial and airway width parameters across the three groups of youngsters in both angular and linear measurements.

Average values for upper and lower airway width in this age group are stated to be in the range of 15 to 20 mm and 9 to 15 mm, respectively.[19,28] Children of group I exhibited upper and lower airway measurements within normal range values. However, intergroup comparison revealed statistically significant differences in upper pharyngeal airway widths among the three groups, with group III children obtaining the narrowest measurements, followed by group II ($p < 0.001$, ►**Table 3**). This was in accordance with a previous study by Paul and Nanda who found greater prevalence of mouth breathing and nasopharyngeal airway obstruction in subjects with class II malocclusions.[29]

There were no statistically significant differences in lower pharyngeal airway widths across groups in our study, and there were no correlations between lower pharyngeal airway width space and craniofacial growth pattern or malocclusion type. This backs up prior research.[21,28,30]

In this study, we found that children in group III had significantly larger ANB angles ($p < 0.001$, ►**Table 1**), which showed a strong negative correlation with upper pharyngeal airway width (–0.575, ►**Tables 6**). These findings are in accordance with those of Ceylan and Oktay who reported that the oropharyngeal space was reduced in subjects with an enlarged ANB angle.[21] Subjects with posterior mandibular rotation exhibited smaller upper airway dimensions, according to Akcam et al.[31] This demonstrates a close link between the upper airway dimension and the jaws' posture.

According to Ferrario et al, orthodontic diagnosis should be based on more than one anteroposterior examination.[32] Other anteroposterior determinants such as the Wits assessment, SNB, A-N Perpendicular, and Pog-N Perpendicular showed statistically significant differences in both groups II and III, supporting the reliability of the ANB angle, which was utilized to identify our participants. Furthermore, the upper airway width was found to have a significant correlation with all of the above anteroposterior tests (►**Tables 5** and **6**).

From these findings, we can infer that children with increased anteroposterior jaw measurements and skeletal mandibular retrognathism were more likely to have narrower upper pharyngeal airway space.

Although our study did not classify children according to their growth patterns, we observed significant increases in the following (vertical) dentofacial measurements, namely SN-MP and *y*-axis, with the greatest increase in group III. The SN-MP and N-Go measurements in group III showed a fair correlation with the upper pharyngeal airway width (►**Table 6**). Further, a significantly smaller Jarabak's ratio was found in group III as compared with group I, reflecting a significantly shorter posterior face height and a vertical growth pattern in this group ($p < 0.001$, ►**Table 2**).

Our findings were in accordance with another study[8] that reported that the nasopharyngeal airway in hyperdivergent individuals was significantly narrower than that in normodivergent individuals.

In our study, we found that preadolescent children with skeletal class II and skeletal class II with mouth breathing had narrower upper pharyngeal airways, which significantly correlated with key anteroposterior and vertical dentofacial measurements, specifically SNB, ANB, SN-MP, and N-Go. These children's dental measurements, such as upper incisor to NA, lower incisor to NB, lower incisor to MP, overbite, and interincisal angle, showed a fair correlation with upper airway width (►**Tables 5** and **6**).

In our study, it is possible that the retruded position of the jaw in children in groups II and III caused the tongue base to be positioned more posteriorly and inferiorly, reducing oropharyngeal airway space. In people with mandibular retrognathism, it is known that the tongue position is more backward, and that contact with the soft palate might result in a posterior placement of the soft palate and restriction of the oropharyngeal airway.[33]

To breathe through the mouth, one must maintain an oral airway, which is achieved by shifting the mandible and tongue downward and backward, as well as tilting the head back. These variations in posture could have an impact on the connection between teeth as well as the direction of jaw growth, which could shift lower and backward.[34]

This work used two-dimensional cephalometric films to assess pharyngeal airway width rather than airway flow capacity, which would have necessitated a more complicated three-dimensional cone-beam computed tomography and dynamic estimation.[35] Further, as we had used lateral head films for airway measurement, we could not measure the

Table 4 Post hoc analysis of results

Dependent variable	(I) Group	(J) Group	Mean difference (I–J)	Standard error	*p*-Value
SNA	Class I	Class II	−0.05	0.815	0.998
		Class II with mouth breathing	−0.3	0.815	0.928
	Class II	Class II with mouth breathing	−0.25	0.815	0.95
SNB	Class I	Class II	3.65	0.852	<0.001
		Class II with mouth breathing	3.45	0.852	<0.001
	Class II	Class II with mouth breathing	−0.2	0.852	0.97
ANB	Class I	Class II	−3.65	0.41	<0.001
		Class II with mouth breathing	−3.8	0.41	<0.001
	Class II	Class II with mouth breathing	−0.15	0.41	0.929
Upper gonial angle	Class I	Class II	3	1.487	0.117
		Class II with mouth breathing	−3.2	1.487	0.089
	Class II	Class II with mouth breathing	−6.2	1.487	<0.001
Lower gonial angle	Class I	Class II	6.45	1.198	<0.001
		Class II with mouth breathing	−2.75	1.198	0.065
	Class II	Class II with mouth breathing	−9.2	1.198	<0.001
Articulare angle	Class I	Class II	−3.75	1.758	0.092
		Class II with mouth breathing	0.1	1.758	0.998
	Class II	Class II with mouth breathing	3.85	1.758	0.082
Saddle angle	Class I	Class II	−1.1	1.536	0.755
		Class II with mouth breathing	−6.35	1.536	<0.001
	Class II	Class II with mouth breathing	−5.25	1.536	0.003
Upper incisor to NA angle	Class I	Class II	−3.5	1.299	0.025
		Class II with mouth breathing	−4.4	1.299	0.004
	Class II	Class II with mouth breathing	−0.9	1.299	0.769
Upper incisor to NA linear	Class I	Class II	−0.25	0.706	0.933
		Class II with mouth breathing	−1.7	0.706	0.05
	Class II	Class II with mouth breathing	−1.45	0.706	0.109
Lower incisor to NB angle	Class I	Class II	−7.1	1.055	<0.001
		Class II with mouth breathing	−3.25	1.055	0.009
	Class II	Class II with mouth breathing	3.85	1.055	0.002
Lower incisor to NB linear	Class I	Class II	0.2	0.669	0.952
		Class II with mouth breathing	−0.2	0.669	0.952
	Class II	Class II with mouth breathing	−0.4	0.669	0.822
Upper incisor to SN	Class I	Class II	0.9	1.75	0.865
		Class II with mouth breathing	−0.2	1.75	0.993
	Class II	Class II with mouth breathing	−1.1	1.75	0.805
Upper incisor to palatal plane	Class I	Class II	−2.7	2.157	0.428
		Class II with mouth breathing	−3.95	2.157	0.169
	Class II	Class II with mouth breathing	−1.25	2.157	0.832
Lower incisor to mandibular plane	Class I	Class II	−7.85	2.181	0.002
		Class II with mouth breathing	0.4	2.181	0.982
	Class II	Class II with mouth breathing	8.25	2.181	0.001
Interincisal angle	Class I	Class II	4.8	2.467	0.135
		Class II with mouth breathing	11.2	2.467	<0.001
	Class II	Class II with mouth breathing	6.4	2.467	0.032
Mandibular plane	Class I	Class II	−0.8	2.17	0.928

Table 4 (*Continued*)

Dependent variable	(I) Group	(J) Group	Mean difference (I–J)	Standard error	*p*-Value
		Class II with mouth breathing	−6	2.17	0.021
	Class II	Class II with mouth breathing	−5.2	2.17	0.051
Mandibular plane to palatal plane	Class I	Class II	9.15	1.086	<0.001
		Class II with mouth breathing	1.1	1.086	0.572
	Class II	Class II with mouth breathing	−8.05	1.086	<0.001
Occlusal to mandibular plane angle	Class I	Class II	3.1	1.311	0.055
		Class II with mouth breathing	−3.6	1.311	0.022
	Class II	Class II with mouth breathing	−6.7	1.311	<0.001
***Y*-axis**	Class I	Class II	−0.5	0.949	0.859
		Class II with mouth breathing	−6.4	0.949	<0.001
	Class II	Class II with mouth breathing	−5.9	0.949	<0.001
Jarabak's ratio	Class I	Class II	−7.10%	0.94%	<0.001
		Class II with mouth breathing	4.35%	0.94%	<0.001
	Class II	Class II with mouth breathing	11.45%	0.94%	<0.001
Length of maxillary base	Class I	Class II	0.45	1.573	0.956
		Class II with mouth breathing	−0.9	1.573	0.835
	Class II	Class II with mouth breathing	−1.35	1.573	0.668
Length of mandibular base	Class I	Class II	−2.55	1.508	0.217
		Class II with mouth breathing	−1.7	1.508	0.501
	Class II	Class II with mouth breathing	0.85	1.508	0.84
SN	Class I	Class II	−1.6	1.136	0.343
		Class II with mouth breathing	−0.1	1.136	0.996
	Class II	Class II with mouth breathing	1.5	1.136	0.39
point A to Nasion perpendicular	Class II	Class II	−1.87	0.571	0.005
		Class II with mouth breathing	−3.28	0.571	<0.001
	Class II	Class II with mouth breathing	−1.41	0.571	0.043
PoG to Nasion perpendicular	Class I	Class II	−0.2	0.788	0.965
		Class II with mouth breathing	3.215	0.788	<0.001
	Class II	Class II with mouth breathing	3.415	0.788	<0.001
Sella to Articulare	Class I	Class II	−0.05	0.95	0.998
		Class II with mouth breathing	3.5	0.95	0.001
	Class II	Class II with mouth breathing	3.55	0.95	0.001
Articulare to gonial angle	Class I	Class II	−4.4	1.216	0.002
		Class II with mouth breathing	−1.25	1.216	0.563
	Class II	Class II with mouth breathing	3.15	1.216	0.032
Gonial to gnathion	Class I	Class II	2.35	1.401	0.223
		Class II with mouth breathing	3.9	1.401	0.02
	Class II	Class II with mouth breathing	1.55	1.401	0.514
Nasion to gonial	Class I	Class II	−9.2	1.278	<0.001
		Class II with mouth breathing	−1.75	1.278	0.364
	Class II	Class II with mouth breathing	7.45	1.278	<0.001
Sella to gnathion	Class I	Class II	−1	1.839	0.85
		Class II with mouth breathing	4.4	1.839	0.052
	Class II	Class II with mouth breathing	5.4	1.839	0.013
Overjet	Class I	Class II	−0.65	0.517	0.425
		Class II with mouth breathing	−4.85	0.517	<0.001

(*Continued*)

Table 4 (*Continued*)

Dependent variable	(I) Group	(J) Group	Mean difference (I–J)	Standard error	*p*-Value
	Class II	Class II with mouth breathing	–4.2	0.517	<0.001
Overbite	Class I	Class II	–1.9	0.474	0.001
		Class II with mouth breathing	0.95	0.474	0.12
	Class II	Class II with mouth breathing	2.85	0.474	<0.001
Upper airway	Class I	Class II	5.2	0.68	<0.001
		Class II with mouth breathing	6.4	0.68	<0.001
	Class II	Class II with mouth breathing	1.2	0.68	0.19
Lower airway	Class I	Class II	0.15	0.399	0.925
		Class II with mouth breathing	0.75	0.399	0.154
	Class II	Class II with mouth breathing	0.6	0.399	0.297

Abbreviations: ANB, difference between SNA and SNB; NA, Nasion – point A; NB, Nasion – point B; PoG, Pogonion; SN, Sella – Nasion; SNA, Sella – Nasion – point A; SNB, Sella – Nasion – point B; SN-MP, Sella Nasion- Mandibular plane angle.

Table 5 Significant correlation among the dentofacial variables and upper airway width in Group II

Group II		**Upper airway**		
Upper incisor to NA linear	Pearson's correlation	0.373		
	Significance: two-tailed	0.105		
	N	20		
Lower incisor to NB angle	Pearson's correlation	–0.348		
	Significance: two-tailed	0.133		
	N	20		
Lower incisor to NB linear	Pearson's correlation	0.316		
	Significance: two-tailed	0.175		
	N	20		
Interincisal angle	Pearson's correlation	0.56		
	Significance: two-tailed	0.01		
	N	20		
Point A to Nasion perpendicular	Pearson's correlation	0.406		
	Significance: two-tailed	0.076		
	N	20		
Sella-Articulare	Pearson's correlation	0.598		
	Significance: two-tailed	0.005		
	N	20		
Overjet	Pearson's correlation	–0.431		
	Significance: two-tailed	0.057		
	N	20		
Negative correlation if sign is negative of the Pearson's correlation				
–0.1	–0.3	–0.5	–0.7	–0.9
Positive correlation if sign is positive of the Pearson's correlation				
0.1	0.3	0.5	0.7	0.9
Poor correlation	Fair correlation	Good correlation	Very good correlation	Excellent correlation

Abbreviations: NA, Nasion – point A; NB, Nasion – point B.
Note: Negative correlation means if one increases, the other decreases. Positive correlation means if one increases or decreases, the other also increases or decreases.

Table 6 Significant correlation among the dentofacial variables and upper airway width in Group III

Group III		Upper airway		
ANB	Pearson's correlation	−0.575		
	Significance: two-tailed	0.008		
	N	20		
Upper incisor to palatal plane	Pearson's correlation	0.536		
	Significance: two-tailed	0.015		
	N	20		
Lower incisor to mandibular plane	Pearson's correlation	0.305		
	Significance: two-tailed	0.191		
	N	20		
Mandibular plane	Pearson's correlation	−0.219		
	Significance: two-tailed	0.353		
	N	20		
Nasion to Gonion	Pearson's correlation	0.32		
	Significance: two-tailed	0.169		
	N	20		
Articulare to gonial angle angle	Pearson's correlation	0.421		
	Significance: two-tailed	0.065		
	N	20		
Overjet	Pearson's correlation	−0.102		
	Significance: two-tailed	0.668		
	N	20		
Overbite	Pearson's correlation	−0.013		
	Significance: two-tailed	0.957		
	N	20		
Negative correlation if sign is negative of the Pearson's correlation				
−0.1	−0.3	−0.5	−0.7	−0.9
Positive correlation if sign is positive of the Pearson's correlation				
0.1	0.3	0.5	0.7	0.9
Poor correlation	Fair correlation	Good correlation	Very good correlation	Excellent correlation

Abbreviations: ANB, difference between Sella – Nasion – point A (SNA) and Sella – Nasion – point B (SNB).
Note: Negative correlation means if one increases, the other decreases. Positive correlation means if one increases or decreases, the other also increases or decreases.

anteroposterior dimensions of the airway, and therefore could not determine three-dimensional volumetric measurements. While the cephalometric view produces a two-dimensional image that is unavoidably constrained, it has the advantage of being simpler and more easily available than computed tomography scanning or magnetic resonance imaging. Although we found significant correlations between many dentofacial measurements and upper pharyngeal airway widths among children with skeletal class II with and without mouth breathing, we recommend that further investigations including a larger sample size of children as well as evaluation of other airway parameters such as airway volume and airflow capacity will allow a better understanding of the relationship between respiratory function and craniofacial morphology.

Conclusion

Our study found significant differences in many of the dentofacial measurements between the children of the three groups, with greater sagittal as well as vertical jaw discrepancies in children with malocclusion. Children with class II malocclusion with mouth breathing had the greatest vertical jaw discrepancy.

We found a significantly decreased upper pharyngeal airway width in children with malocclusion, with the narrowest airway observed in children with class II malocclusion with mouth breathing. No significant differences were observed in lower airway widths among the groups.

Based on the findings of this study, we may conclude that children with class II malocclusion with mouth breathing seemed to have significant narrowing of the upper airways. Certain dentofacial characteristics such as increased sagittal and vertical discrepancy and anterior tooth proclination seem to be definitely correlated with a decreased upper pharyngeal airway width, which could help identify children at increased risk of sleep disordered breathing.

Conflict of Interest
None declared.

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