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Cephalometric differences in grades II and IV adenoid hypertrophy: A cross-sectional study

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Abstract

OBJECTIVES: This study aims to determine whether there were cephalometric changes between grades II and IV adenoid hypertrophy.

METHODS AND MATERIALS: A cross-sectional study was conducted on 120 6–12-year-old patients selected from the ear, nose, and throat department at Imam Al-Hussein Medical City in Karbala. Patients were classified into three groups (each = 40) based on endoscopic findings: control, grade II, and grade IV. The findings were confirmed with cephalometric radiographs. Specific cephalometric points were identified to measure sella-nasion-point A (SNA), sella-nasion-point B (SNB), point A-nasion-point B (ANB), sella-nasion-pogonion (SNPog), sella nasion plane-palatal plane (SNPP), palatal plane-mandibular plane (PPMP), sella nasion plane-mandibular plane (SNMP), saddle, articular, gonial angles, and the *y*-axis. Additionally, superior-posterior airway space (SPAS), posterior air way space (PAS), mandibular plane-hyoid bone (MP-H), third cervical vertebra-hyoid bone (C3-H), total anterior facial height (TAFH), total posterior facial height (TPFH), upper anterior facial height (UAFH), lower anterior facial height (LAFH), and the Jarabak ratio were measured.

RESULTS: Analysis of variance (ANOVA) and Welch tests indicated statistically significant differences ($P < 0.05$) among the three groups in SNA, SNB, SNPog, PPMP, SNMP, gonial angle, *y*-axis, SPAS, PAS, MP-H, and the Jarabak ratio. Tukey's honestly significant difference (HSD) and Games-Howell tests indicated a statistically significant difference between grade II and grade IV in SNA, SNMP, *y*-axis, SPAS, PAS, MP-H, and Jarabak ratio.

CONCLUSION: The present study demonstrated that craniofacial changes start to occur at the moderate adenoid enlargement throughout the downward backward mandibular rotation. More changes would become evident at the severe stage; therefore, an urgent medical intervention and the establishment of nasal breathing by orthodontic treatment with breathing activity would be needed.

Keywords:

Adenoid hypertrophy, cephalometric radiograph, cross-sectional study, mouth breather

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Introduction

The adenoid is a lymphoid tissue that is very small at birth; however, due to frequent bacterial infections during immune system development, it can potentially block the airway. Normally, the adenoid tissue reaches its maximum size between 3 and 7 years of age and gradually regresses.[1–3]

A relationship between mouth breathing caused by adenoid hypertrophy and the generation of malocclusions has long been hypothesized, and esthetic improvement is a major concern for orthodontic patients with adenoid hypertrophy and mouth breathing. Mouth breathing is strongly connected with all occlusal disorders analyzed. Therefore, people who are more predisposed to hereditary causes and an unfavorable growth pattern would also display a "risk of developing malocclusion" associated with unhealthy behaviors.[4]

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The resulting "adenoid face" is characterized by incompetent lips, a back-position of the hyoid bone, a constructed (or V-shaped) upper dental arch, a back-position of lower incisors, a greater than average anterior face height, and an excessive mandibular plane angle.[5–7] Additionally, patients have narrow nostrils, a high-arched palate, and a gummy smile and display a malocclusion of class II or III, with a high prevalence of posterior crossbite and anterior open bite.[8–10] Children suffering from mouth breathing rotate their mouths in a backward and downward orientation, causing a class II malocclusion and a skeletal class II profile with enhanced overjet and vertical growth.[11] The muscles responsible for opening the mouth depress the jaw, displacing the mandible distally and slowing its growth.

Some instances of class III malocclusion may involve mouth breathing as a contributing factor; children who breathe through their mouths are more likely to have an open bite and a low tongue posture, with persistent diversion of the mandibular condyle from the fossa, which may be a growth stimulus.[12] A longitudinal and horizontal maxillary skeletal deficit may also result from insufficient tongue sit and push against the palate and upper jaw, a class III malocclusion with reduced or reverse overjet.[9]

Addressing the underlying causes of mouth breathing as early as possible and providing early orthodontic care from a young age to aid in bone development is essential; it would allow for more stable results to be achieved, fewer permanent teeth to be extracted, higher levels of parental satisfaction, and reduced treatment duration with fewer complications of enamel decalcifications and gum diseases.[13]

Cephalometric analysis indicated that the individuals have a higher lower anterior face height, an obtuse mandibular plane angle, slower ramus growth due to aberrant nocturnal growth hormone release,[14] and an elongated *y*-axis.[15]

Studies on the effects of adenoid size and the different levels of nasal obstruction on craniofacial changes remain insufficient. Our study aims to bring more insight into the subject.

Materials and Methods

This cross-sectional study was ethically approved by the ethical approval committee (No. 818), College of Dentistry/University of Baghdad, on May 18, 2023. A hundred and twenty patients aged 6–12 years were selected from the ear, nose, and throat (ENT) department at Imam Al-Hussein Medical City in Karbala and diagnosed by an otolaryngologist to detect the adenoids. The ENT specialist examined each patient to include or exclude the sample using a flexible Karl Storz endoscope machine (model 495xx, 69495xx). The samples were allocated into three groups based on the endoscopic classification system of adenoids [Figure 1] proposed by Cassano *et al*.[16] Grade I corresponds to the adenoid tissue covering less than 25% of the choanal openings; grade II corresponds to the adenoid tissue covering less than 50% of the choanal openings, with the Eustachian tube visible; grade III corresponds to a covering of about 75%, with the Eustachian tube slightly involved; and grade IV refers to a covering of over 75%, with the Eustachian tube completely covered. The 120 patients were divided into control, grade II, and grade IV (each = 40). The control group is free from any systemic disease and from adenoids diagnosed by the otolaryngologist using the endoscope. Subjects with systemic diseases, handicaps, previous maxillofacial trauma, past adenoidectomy, and grades I and III adenoids were excluded.

The selected samples were confirmed with a cephalometric radiograph taken at the department of radiology at Imam Al-Hussein Medical City in Karbala, using the Hyperion X9 Pro professional 3-in-1 full-touch imaging system by the same X-ray specialist at centric occlusion in natural head position.[17] The head was fixed by ear rods laterally and a plastic stopper (nasion support) on the bridge of the nose anteriorly, fixing the Frankfort plane horizontally.[18] The central ray of the X-ray beam entered through the right external auditory meatus of the subject and exited from the left side meatus.

The cephalometric landmarks used in this study were sella (S), nasion (N), articulare (Ar), posterior nasal spine (PNS), anterior nasal spine (ANS), A-point, B-point, pogonion (Pog), gonion (Go), gnathion (Gn), and menton (Me).[19–21] Multiple cephalometric angles and lines were used [Tables 1, 2 and Figures 2, 3].

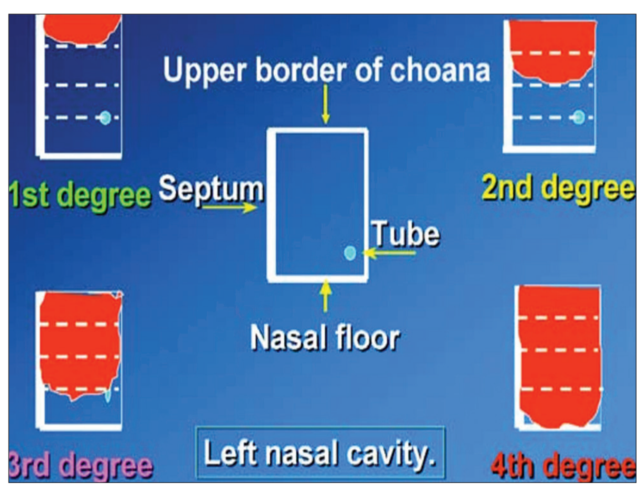

Figure 1: Diagram of the endoscopic grading of adenoid hypertrophy[22]

Table 1: Cephalometric variables (angular measurements) used in this study[7,23-26]

Variables	Description	Diagnostic values
SNA°	Angle formed by the SN line and the NA line	Maxillary relation to the cranial base in the sagittal plane
SNB°	Angle formed by the SN line and the NB line	Mandibular relation to the cranial base in the sagittal plane
ANB°	Difference between the SNA and the SNB	Maxillary relation to the mandible in the sagittal plane.
SNPP°	Angle formed by the SN and the palatal plane	Maxillary inclination related to the anterior cranial base
PPMP°	Angle between the palatal and mandibular plane	Maxillary relation to the mandible in the vertical plane.
SNMP°	Angle between the SN and the mandibular plane	Mandibular inclination related to the anterior cranial base
SNPog°	Angle formed by the SN plane and the Pog	Mandibular position of the cranium in the sagittal plane
y- axis°	Angle formed by the SN line and the S-GN line	Mandibular position relative to the cranial base
Saddle angle°	Angle formed between the nasion, sella, and Ar	Determine the position of the glenoid fossa and the mandibular condyle
Articular angle°	Angle formed between the sella, Ar, and Go	Determine the mandibular position and bite opening
Gonial angle°	Angle formed between the Ar, Go, and Gn	Relation of the ramus to the body of the mandible Indicating the mandibular rotation

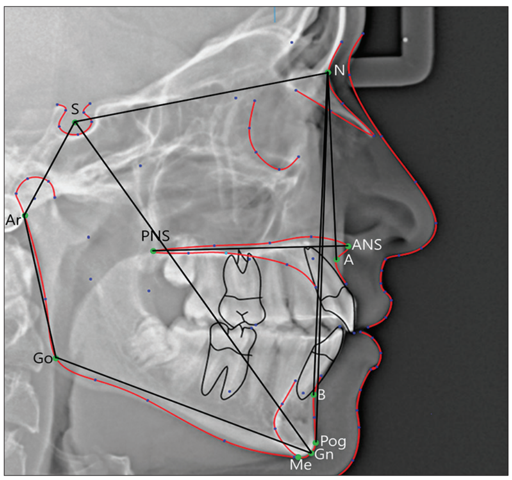

Figure 2: Cephalometric radiograph of the angular measurements modified[27]

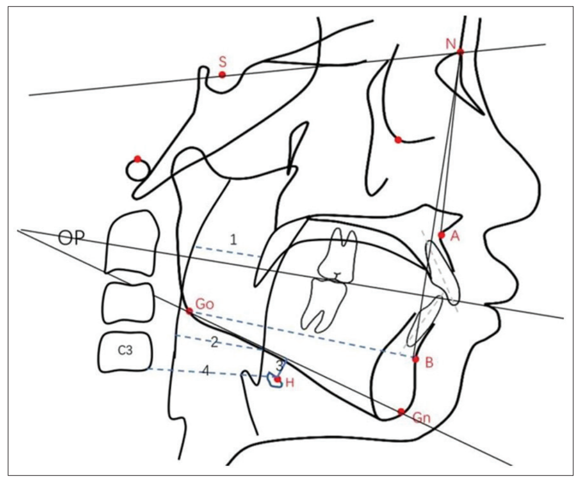

Figure 3: Drawing of the linear measurements of the airways. 1, SPAS; 2, PAS; 3, MP-H; 4, C3-H[7]

Tracing processes were made using Autodesk AutoCAD 2020 to facilitate the cephalometric analysis. The AutoCAD software can determine the linear and angular measurements of any digital image.[28]

Statistical analysis

The statistical analysis was performed using the Statistical Package for Social Science (SPSS) v. 26. Intra-examiner and inter-examiner calibration using intraclass correlation coefficient (ICC) was used on 20 randomly selected samples, and the results displayed a high degree of agreement. The Shapiro-Wilk test was used to test the normality of the data. Mean, standard deviation, maximum, and minimum were used to describe the data. One-way analysis of variance (ANOVA) and Welch tests were employed to detect the differences among the control, grade II, and grade IV. Each group was compared with one another using Tukey's honestly significant difference (HSD) and Games-Howell tests with $P < 0.05$.

Results

This study was conducted on 120 participants (mean age, 9.13 ± 1.97; range, 6–12 years; 60.8% male; 39.2% female). Using one-way ANOVA and Welch tests, the mean distribution among groups showed statistically significant differences at $P < 0.05$ in SNA, SNB, SNPog, PPMP, SNMP, gonial angle, *y*-axis, SPAS, PAS, MP-H, and the Jarabak ratio [Tables 3-5].

Tukey's HSD and Games-Howell tests indicated a statistically significant difference at $P < 0.05$ between grade IV and grade II in SNA, SNMP, *y*-axis, SPAS, PAS, MP-H, and Jarabak ratio. The two tests indicated a statistically significant difference in SNA, SNB, SNPog, PPMP, SNMP, gonial angle, *y*-axis, SPAS, PAS, MP-H, and Jarabak ratio between grade IV and control groups. Finally, a statistically significant difference in the PPMP, *y*-axis, and SPAS was observed between grade II and control groups [Tables 6-8].

Table 2: Cephalometric variables (linear measurements) used in this study[7,23-26]

Variables	Description	Diagnostic values
SPAS (mm)	Width of the airway back to the soft palate along a line aligned to the Go-B point plane	Blockage of the superior-posterior airway space.
PAS (mm)	Distance between a point at the bottom of the tongue and another point on the back wall of the pharynx should be parallel to the GO-point B line	Blockage of posterior airway space
MP-H (mm)	Distance from the most anterior-superior point of the hyoid bone to the mandibular plane, calculated at right angles to the latter	Hyoid bone position relative to the mandibular plane
C3-H (mm)	Distance from C3 to H, where C3 is the most anterior-inferior point of the third cervical vertebra	Hyoid bone position relative to the third cervical vertebra
TAFH (mm)	Linear distance from point N to point Me	Increase with the vertical growth pattern
UAFH (mm)	Linear distance from point N to point ANS	Affected by the growth pattern
LAFH (mm)	Linear distance from point ANS to point Me	Affected by the growth pattern
TPFH (mm)	Linear distance from point S to point Go	Decrease with a vertical growth pattern
Jarabak ratio	Posterior facial height/anterior facial height×100	Ratio lower than 62% describes a vertical growth pattern, whereas a ratio higher than 65% expresses a horizontal growth pattern

Table 3: Descriptive and inferential statistics (Welch and ANOVA) for the SNA, SNB, ANB, SNPog, SNPP, PPMP, and SNMP

Variables	Groups	Mean	Std. deviation	Min	Max	Statistics (Welch)/*F* (ANOVA)	*P*
SNA°	Control	81.8	3.12	76	89	5.11*	**0.007**
	Grade II	81.48	3.61	74	91		
	Grade IV	79.43	4.02	71	91		
SNB°	Control	78.33	2.94	71	84	5.36*	**0.006**
	Grade II	77.28	3.85	69	84		
	Grade IV	75.73	3.86	69	86		
ANB°	Control	3.48	1.41	1	6	2.49*	0.087
	Grade II	4.4	2.04	0	9		
	Grade IV	3.85	2.07	0	8		
SNPog°	Control	78.68	3.14	72	88	6.53*	**0.002**
	Grade II	77.55	3.9	69	85		
	Grade IV	75.75	3.86	70	85		
SNPP°	Control	6.85	2.32	3	11	0.69*	0.502
	Grade II	6.3	3.3	0	13		
	Grade IV	7.13	3.78	1	17		
PPMP°	Control	24.78	4.19	17	37	11.51*	**0.000**
	Grade II	27.55	5.19	16	40		
	Grade IV	30.2	5.67	19	41		
SNMP°	Control	31.53	3.64	26	41	15.6**	**0.000**
	Grade II	33.83	4.99	23	45		
	Grade IV	37.45	5.65	23	49		

*ANOVA; **Welch. All values marked in bold are statistically significant at $P<0.05$

Discussion

Many studies have attempted to correlate mouth breathing with the development of malocclusion. Since the most common cause of oral breathing is adenoid hypertrophy,[29,30] this study aimed to link different levels of adenoid enlargements with craniofacial development. The relationship between oral breathing caused by adenoid hypertrophy and the development of malocclusions has long been hypothesized, and our study confirms this link.

Hypertrophy of the adenoid tissues is associated with a narrowing of the upper airways, causing postural adaptation to maintain breathing and craniofacial changes.[14,31] Muñoz and Orta[32] reported that craniofacial changes did not disappear after adenoidectomy, instead necessitating orthodontia with myofunctional reeducation to reduce oral breathing and reestablish a correct craniofacial position.[33]

Oral breathing, a low tongue position, and increased lower anterior facial height were obvious at three years old but more commonly noticed after five. The deleterious impact of decreased naso-respiratory function was virtually complete by puberty; therefore, the 6–12 age range was selected for this study.[32]

Table 4: Descriptive and inferential statistics (Welch and ANOVA) for the saddle, articular, and gonial angles, *y*-axis, SPAS, and PAS

Variables	Groups	Mean	Std. deviation	Min	Max	Statistics (Welch)/*F* (ANOVA)	*P*
Saddle angle°	Control	121.95	6.04	111	139	0.13*	0.876
	Grade II	121.6	4.44	112	130		
	Grade IV	122.2	5.12	114	134		
Articular angle°	Control	141.23	5.38	125	153	1.57*	0.213
	Grade II	142.98	5.86	132	153		
	Grade IV	143.33	5.78	133	155		
Gonial angle°	Control	128.63	5.33	119	140	3.37*	**0.038**
	Grade II	129.48	6.31	113	142		
	Grade IV	132	6.43	120	145		
Y-axis°	Control	65.93	2.77	59	73	18.45**	**0.000**
	Grade II	68.1	3.61	62	75		
	Grade IV	70.75	4.27	60	77		
SPAS (mm)	Control	13.22	2.01	9.2	17.3	232.36*	**0.000**
	Grade II	9.76	2.07	5.37	14.47		
	Grade IV	3.18	2.26	0	8.6		
PAS (mm)	Control	11.66	2.7	6	18.1	11.66*	**0.000**
	Grade II	11.06	3.24	3.79	21.69		
	Grade IV	14.18	3.24	8.5	23		

*ANOVA; **Welch. All values marked in bold are statistically significant at $P<0.05$

Table 5: Descriptive and inferential statistics (Welch and ANOVA) of the MP-H, C3-H, TAFH, TPFH, UAFH, LAFH, and the Jarabak ratio

Variables	Groups	Mean	Std. deviation	Min	Max	Statistics (welch)/*F* (ANOVA)	*P*
MP-H (mm)	Control	12.89	5.01	3.7	26	15.53*	**0.000**
	Grade II	11.75	4.03	3.25	18.9		
	Grade IV	17.25	4.87	6.7	26.95		
C3-H (mm)	Control	29.22	2.64	23.4	36	2.08*	0.129
	Grade II	27.96	2.66	20.5	33.15		
	Grade IV	28.78	3.08	23	39.6		
TAFH (mm)	Control	99.02	5.62	85	113	1.63*	0.200
	Grade II	100.55	5.54	87.31	111.79		
	Grade IV	101.54	7.53	87	122		
TPFH (mm)	Control	63.95	4.89	52.6	71.64	1.40*	0.252
	Grade II	63.81	4.54	52.55	75.1		
	Grade IV	62.26	5.57	50.5	75.4		
UAFH (mm)	Control	43.98	3.47	35	50	0.24*	0.784
	Grade II	43.45	3.53	36.26	50.29		
	Grade IV	43.85	3.57	37	49.81		
LAFH (mm)	Control	55.06	3.71	48.3	64.4	2.78**	0.069
	Grade II	57.06	4.1	46.53	66.56		
	Grade IV	56.66	6.6	39	73.1		
Jarabak ratio	Control	64.2	2.63	58	69	7.52*	**0.001**
	Grade II	63.03	3.81	53	70		
	Grade IV	61.1	4.21	52	73		

*ANOVA; **Welch. All values marked in bold are statistically significant at $P<0.05$

Cephalometric differences between nasal and mouth breathers were found. Lateral cephalometric radiographs were used to detect the craniofacial morphology and evaluate the airways.[32] A nasoendoscope was used to examine the nasal area for choanal atresia, nasal stenosis, tumors, polyps, and adenoid size, providing a direct visualization of the nasal area.[34] A lateral cephalogram was used to detect the adenoid size. Patient cooperation was essential during the cephalometric exam; the patient must be positioned correctly, not crying or swallowing, since that could affect the soft palate and give a false reading.[35] That was very difficult to obtain, especially with children, and the operator tried his best throughout the parent's education and the child's distraction to get a correct cephalometric image.

Statistical analysis of the SNA and SNB indicated a statistically significant difference at $P < 0.05$ among the

Table 6: Comparative values between three groups for the SNA, SNB, ANB, SNPog, SNPP, PPMP, and SNMP using Tukey's HSD and Games-Howell tests

Tukey's HSD/Games-Howell				
Variables	Between groups	Mean difference	Std. error	P
SNA°	Grade IV and grade II	– 2.050*	0.805*	**0.033**
	Grade IV and control	−2.375*	0.805*	**0.011**
	Grade II and control	−0.325*	0.805*	0.914
SNB°	Grade IV and grade II	−1.550*	0.799*	0.132
	Grade IV and control	−2.600*	0.799*	**0.004**
	Grade II and control	−1.050*	0.799*	0.390
ANB°	Grade IV and grade II	−0.550*	0.417*	0.387
	Grade IV and control	0.375*	0.417*	0.642
	Grade II and control	0.925*	0.417*	0.072
SNPog°	Grade IV and grade II	−1.800*	0.817*	0.075
	Grade IV and control	−2.925*	0.817*	**0.001**
	Grade II and control	−1.125*	0.817*	0.356
SNPP°	Grade IV and grade II	0.825*	0.713*	0.481
	Grade IV and control	0.275*	0.713*	0.921
	Grade II and control	−0.550*	0.713*	0.721
PPMP°	Grade IV and grade II	2.650*	1.131*	0.054
	Grade IV and control	5.425*	1.131*	**0.000**
	Grade II and control	2.775*	1.131*	**0.041**
SNMP°	Grade IV and grade II	3.625**	1.192**	**0.009**
	Grade IV and control	5.925**	1.063**	**0.000**
	Grade II and control	2.300**	0.977**	0.055

*Tukey HSD; **Games-Howell; all values marked in bold are statistically significant at $P<0.05$

Table 7: Comparative values between three groups for the saddle, articular, and gonial angles, *y*-axis, SPAS, and PAS using Tukey's HSD and Games-Howell tests

Tukey's HSD/Games-Howell				
Variables	Between groups	Mean difference	Std. error	P
Saddle angle°	Grade IV and grade II	0.600*	1.171*	0.866
	Grade IV and control	0.250*	1.171*	0.975
	Grade II and control	−0.350*	1.171*	0.952
Articular angle°	Grade IV and grade II	0.350*	1.270*	0.959
	Grade IV and control	2.100*	1.270*	0.228
	Grade II and control	1.750*	1.270*	0.356
Gonial angle°	Grade IV and grade II	2.525*	1.352*	0.153
	Grade IV and control	3.375*	1.352*	**0.037**
	Grade II and control	0.850*	1.352*	0.805
Y-axis°	Grade IV and grade II	2.650**	0.884**	**0.010**
	Grade IV and control	4.825**	0.804**	**0.000**
	Grade II and control	2.175**	0.720**	**0.010**
SPAS (mm)	Grade IV and grade II	−6.57900*	0.47311*	**0.000**
	Grade IV and control	−10.03875*	0.47311*	**0.000**
	Grade II and control	−3.45975*	0.47311*	**0.000**
PAS (mm)	Grade IV and grade II	3.12600*	0.68692*	**0.000**
	Grade IV and control	2.52275*	0.68692*	**0.001**
	Grade II and control	−0.60325*	0.68692*	0.655

*Tukey HSD; **Games-Howell; all values marked in bold are statistically significant at $P<0.05$

three groups. The maxilla and mandible were more retrognathic in the grade IV group, agreeing with the systematic review and meta-analysis of Zheng *et al.*[36] The retrognathia of the maxilla could be due to the obstruction of the upper airway, causing narrowing and reduction of the airflow in the nasal cavities, hypoplasia of the nasal and paranasal areas, and the maxillary sinus. Mouth breathers try to open their mouth during breathing, and the muscles responsible for mouth opening depress and dislocate the mandible posteriorly.[4] The mandible was more posterior, which could be explained by the anterior and inferior positions of the tongue when the nasopharynx is filled with adenoid tissue.[37] An inferior tongue position causes a lack of tongue pressure against the palate, causing maxilla underdevelopment.[38] Souki *et al.*[39] reported that a small corpus of the mandible could decrease the SNB angle in mouth breathers. Regarding the SNA and SNB, no significant differences were observed between the control and grade II groups, which could be explained by the airways not being obstructed enough to cause cranial changes.

No significant differences ($P > 0.05$) were observed among groups for the ANB, agreeing with other studies.[32,36,40] The sagittal malocclusion was not correlated with the degree of nasopharyngeal obstruction,[41] which could be explained by the fact that most changes in the skeletal pattern were associated with changes in the oropharynx more than nasopharynx.[40]

SNPog determined the basal position of the mandible related to the cranium in the sagittal plane. A highly significant difference ($P < 0.01$) was observed among groups. The difference was greater between the control and grade IV groups and was caused by the retrognathic mandible. The results correlated with the SNB and agreed with previous research.[42]

Although an increase in the mean SNPP angle was observed in grade IV compared with other groups, no significant difference ($P > 0.05$) as observed among the three groups, agreeing with the previous study.[43] The SNPP angle indicated the maxillary inclination related to the cranial base. Systematic review and meta-analysis demonstrated that the palatal plane angle increases in mouth breathers due to its inclination being correlated with the increase of the maxilla-mandibular plane angle.[7]

Other authors[44] found a negative correlation between mandibular plane angle and palatal plane angle and added that the palatal plane inclination was not a major contributing factor to the vertical growth pattern, which could be explained by the smaller sample size of their study.

The SNMP and PPMP angles displayed a significant difference ($P < 0.01$) among the three groups, consistent

Table 8: Comparative values between the three groups for the MP-H, C3-H, TAFH, TPFH, UAFH, LAFH, and the Jarabak ratio using Tukey's HSD and Games-Howell tests

Variables	Between groups	Mean difference	Std. error	P
	Tukey HSD/Games-Howell			
MP-H (mm)	Grade IV and grade II	5.49775*	1.04146*	**0.000**
	Grade IV and control	4.35875*	1.04146*	**0.000**
	Grade II and control	−1.13900*	1.04146*	0.52
C3-H (mm)	Grade IV and grade II	0.82200*	0.62643*	0.391
	Grade IV and control	−0.43675*	0.62643*	0.766
	Grade II and control	−1.25875*	0.62643*	0.114
TAFH (mm)	Grade IV and grade II	0.99475*	1.40779*	0.76
	Grade IV and control	2.52600*	1.40779*	0.176
	Grade II and control	1.53125*	1.40779*	0.524
TPFH (mm)	Grade IV and grade II	−1.54975*	1.12265*	0.354
	Grade IV and control	−1.69075*	1.12265*	0.292
	Grade II and control	−0.14100*	1.12265*	0.991
UAFH (mm)	Grade IV and grade II	0.39700*	0.78764*	0.87
	Grade IV and control	−0.13200*	0.78764*	0.985
	Grade II and control	−0.52900*	0.78764*	0.78
LAFH (mm)	Grade IV and grade II	−0.39800**	1.22833**	0.944
	Grade IV and control	1.60025**	1.19678**	0.38
	Grade II and control	1.99825**	0.87454**	0.064
Jarabak ratio	Grade IV and grade II	−1.925*	0.807*	**0.049**
	Grade IV and control	−3.100*	0.807*	**0.001**
	Grade II and control	−1.175*	0.807*	0.316

*Tukey HSD; **Games-Howell. All values marked in bold are statistically significant at $P<0.05$

with other studies.[7,32,36,38,43] Those angles could be affected by any mandibular rotation or ramus height alteration.[45,46] Additionally, the increase in the anterior facial height associated with the obtuse gonial angle could alter those angles. No statistically significant difference was found in the mandibular plane angle, which could be explained by the small sample size.[47,48]

No statistically significant difference ($P > 0.05$) was observed for the saddle and articular angle, indicating a similar position of the glenoid fossa and the mandibular condyle in the three groups. However, the statistical significance ($P < 0.05$) observed for the gonial angle agreed with other studies.[5,38] Systematic review and meta-analysis indicated an increased gonial angle in mouth breathers.[36] The gonial angle describes the relationship between the mandibular ramus and body and is greatly affected by the rotational tendency of the mandible. Mouth breathers had a great vertical growth tendency, which explained the increase of the gonial angle due to the downward-backward rotation of the mandible.

Lessa *et al.*[49] disagreed with the previous results; they pointed out that the gonial angle of mouth and nasal breathers were not statistically different, which may be due to the smaller sample size of the study (only 60 subjects) and the younger age (6–12).

An increase in the *y*-axis angle with a highly significant difference ($P > 0.01$) among groups indicated a vertical growth pattern, agreeing with other studies.[15,36,38] Systematic review and meta-analysis indicated an increase in the *y*-axis in mouth breathers, which could be explained by the dorsal mandibular rotation and an increase in the anterior facial height, indicating a vertical growth pattern.[36]

A high significant difference ($P < 0.01$) among groups was found for the SPAS (describe the blockage of the superior-posterior airway space) and PAS (refer to the blockage of the posterior airway space). A reduction of the SPAS was found in mouth breathers and was associated with the size of the adenoid tissues compared to nasal breathers.[7,32,50] Although most studies found a reduction of the PAS,[7,50] this study demonstrated an increase in PAS that is explained by the anterior tongue base position, which is mostly found in patients with tonsil hypertrophy as compensation to assist breathing.[51–53] In this study, subjects in grade IV with adenoid hypertrophy could be associated with tonsillar enlargement since both of them are parts of Waldeyer's ring, which acts together as a first-line deference against pathogens.[54]

MP-H and C3-H describe the hyoid bone position using the mandibular plane and the third cervical spine. A significant difference ($P < 0.01$) was found among groups regarding the MP-H, while no difference was found for the C3-H among groups.

The hyoid bone was described as floating since it had no articulation with the surrounding bones (cranium, mandible, and pharynx) but was connected to them by muscles and ligaments. Its position was affected by surgical changes in the mandibular position, even after orthodontic treatment.[55,56]

Cuccia *et al.*[57] suggested that mouth breathers develop an extended head position and a lower position of the hyoid bone. They added that oral breathing causes elevation with a greater head extension related to the cervical spine, reduced cervical lordosis, and a higher extension of the atlantooccipital joint to maintain a natural head position and increase the dimensions of the airways. This process is associated with lowering the hyoid bone position, which agrees with the study results. A lowered tongue position, decreased nasopharyngeal space, and increased craniocervical extension were the main causes of the lowered hyoid bone position.[29]

The abovementioned results were contraindicated by Muñoz and Orta[32] and Mohamed *et al.*[29] Muñoz and Orta[32] concluded that mouth breathers had an elevated hyoid bone position compared with nasal breathers, while

Mohamed *et al*.[29] studied the position of the hyoid bone in different age groups (7–9 and 10–11) and concluded that the hyoid bone was more anterior and more inferior in older nasal breathers. The two studies used tracing with Rocabado's triangle, which may explain why their results differed from this study. The hyoid bone elevation is due to the contraction and increased electrical activity of the mouth-opening muscles, including the suprahyoid muscles, in mastication and maximum occlusion, compared to the masseter muscles.[58]

Generally, studying the hyoid bone position using the mandibular plane or Rocabado's triangle uses reference points that could vary with the changing of the mandibular rotation. Like for mouth breathers, the mandible descends (posterior rotation), and C3 changes its position when the cervical kyphosis is rectified; therefore, choosing a stable point on the cranium (sella turcica) is better.[32]

A reduction in distance between C3 and the hyoid bone was previously reported in mouth breathers,[32,59] which explained the posterior position of the hyoid bone, which comes in line with the results of this study, in which both grade II and grade IV were less than the control group. However, statistically, there were no significant differences ($P > 0.05$). This discrepancy could be explained by the increase in the head extension to improve the breathing pattern[60] and the action of the suprahyoid muscles that pull the hyoid bone superiorly and posteriorly in mouth breathers.[32]

A systematic review and meta-analysis discussed the craniofacial changes associated with mouth breathers and their consequences on facial height changes. As discussed previously, nasopharyngeal obstruction causes a downward and backward rotation of the mandible and an increased inclination of the mandibular plane, with a higher mandibular plane angle and vertical growth pattern associated with an increase in the TAFH, LAFH, and reduced TPFH,[36] agreeing with our results. However, no significant differences ($P > 0.05$) were found among the groups.

Mouth breathing was the main causative factor of the vertical growth pattern[48] and was associated with an increase in the anterior facial height due to the mandibular clockwise rotation.[61]

Souki *et al*.[39] studied the effect of nasal obstruction on different age groups (primary and permanent dentition) and found a significant difference in the LAFH between mouth breathing and nasal breathing groups, indicating that facial height might also be affected by skeletal maturation. Therefore, to better understand facial morphology, the Jarabak ratio (posterior facial height to anterior facial height) gave an acceptable result.

Multiple studies reported a decrease in the Jarabak ratio of mouth breathers, representing an increase in anterior facial height and a decrease in posterior facial height, reflecting the clockwise rotation of the mandible with the vertical growth pattern of the anterior portion of the face.[49,58] Those reports agreed with our study, which indicated a significant difference ($P < 0.05$) in the Jarabak ratio among groups.

The limitation of this study

With the strength of this study, further recommendations could be suggested, such as doing a serial adenoid evaluation (longitudinal study) to minimize the potential variation. Examination of the nasopharyngeal airway using cone-beam computed tomography (CBCT) at different ages is important because, with aging, the nasopharynx grows, and the adenoid diminishes during and after puberty. Expanding the study sample and providing more specifications on the sample age are recommended.

Conclusion

This study demonstrated that craniofacial changes start at moderate adenoid enlargement throughout the changes in the *y*-axis angle and PPMP, which refer to the downward backward mandibular rotation. More changes would occur at the severe stage; therefore, urgent medical intervention and establishment of nasal breathing by orthodontic treatment with breathing activity would be applied.

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Conflicts of interest

There are no conflicts of interest.

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