

Significant changes in respiration, craniofacial development, and posture: A multidisciplinary study on the effects of adenoidectomy

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Introduction: The objective of this study was to assess changes in respiratory patterns, craniofacial development, and head and neck and overall body posture in children who have undergone early adenoidectomy and those who have not. **Methods:** This multidisciplinary study was conducted in collaboration with the Departments of Otolaryngology, Physical Therapy and Rehabilitation, and Orthodontics. Patients diagnosed with adenoid vegetation who did not undergo surgery (group 1: $n = 31$; mean age 7.90 ± 1.55 years) and those who underwent early surgery (group 2: $n = 30$; mean age 8.30 ± 1.39 years) were included. The control group (group 3: $n = 30$; mean age 8.30 ± 1.39 years) consisted of subjects with no pathology causing respiratory obstruction and normal nasal breathing. Lateral and posteroanterior cephalograms, dental casts, the Nasal Obstruction Symptom Evaluation scale, and peak nasal inspiratory flow measurements were used for evaluation. Postural analysis was conducted using 3-dimensional motion analysis with Kinect sensors. Statistical comparisons were performed among groups. **Results:** A difference was found among groups in respiratory parameters, and correlation analysis showed that these parameters were consistent with each other ($P < 0.05$). However, no difference was observed in posture measurements among the groups ($P > 0.05$). Although statistically significant differences were found among groups in the skeletal, dental, and soft tissue cephalometric parameters, significant correlations were also found between intergonial, interzygomatic distance, and corpus lengths with the respiratory parameters ($P < 0.05$). Although no significant correlation was observed between the dental cast analysis values and the respiratory parameters, there was a statistically significant difference in intercanine distance among groups ($P < 0.05$). **Conclusions:** Early adenoidectomy improves respiratory and craniofacial growth, resembling normal nasal breathing. Delayed surgery leads to persistent mouth-breathing and negative growth outcomes. Close collaboration between otolaryngologists and orthodontists is essential for optimal management. (Am J Orthod Dentofacial Orthop 2025; ■: ■-■)

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The data that support the findings of this study are available from the corresponding author upon reasonable request.

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A properly functioning airway is widely considered important for the balanced growth and development of craniofacial structures. The pharyngeal airway is anatomically divided into 3 regions: the nasopharynx, oropharynx, and laryngopharynx.¹ The nasopharynx serves as the primary route for air inhaled through the nose, and pathologic conditions affecting this region may alter typical respiratory patterns. When airway resistance increases because of anatomic or functional factors such as adenoid hypertrophy, nasal breathing may gradually shift toward oral respiration.

Mouth breathing has been associated with a distinct craniofacial appearance often referred to as “adenoid facies,” which may include a long and narrow face, reduced nostril width, a short and hypotonic upper lip, a hypertrophic lower lip, a high and narrow palatal vault,

unilateral or bilateral posterior crossbite, mandibular retrognathia, increased lower anterior facial height, an open-mouth posture, and forward head positioning.²

Early diagnosis and management of adenoid hypertrophy are generally recommended, as altered respiratory patterns are thought to influence dentofacial growth and development. Treatment options include pharmacologic therapy and surgical removal of the adenoids (adenoidectomy).³ However, persistent respiratory dysfunction may continue to present in some patients after adenoidectomy. In such patients, further evaluation by pediatricians may be necessary to identify additional anatomic obstructions. Despite its clinical relevance, there is currently no standardized protocol to assess postoperative respiratory patterns or to facilitate the transition from habitual oral to nasal breathing.

Recent studies have demonstrated that mouth breathing significantly affects craniofacial development, particularly in growing children. Mouth breathing has been associated with various dentofacial alterations, including adenoid facies, a convex facial profile, increased lower facial height, Class II malocclusion, posterior crossbite, and anterior open bite. In addition, it leads to postural adaptations, such as increased cranio-cervical extension, as a compensatory mechanism to maintain airway patency. A comprehensive narrative review published in 2025, which analyzed studies involving children aged 6–18 years, confirmed that mouth breathing induces not only craniofacial morphologic changes but also significant alterations in mandibular, lingual, and palatal positioning. Although the causal relationship between mouth breathing and malocclusion remains a topic of debate, current evidence supports the view that mouth breathing acts as a significant risk factor in the development and prognosis of malocclusion.⁴

Various tools have been employed to assess head, neck, and overall body posture, ranging from simple posture observation charts to photographic analysis and advanced motion capture systems using segment-dependent passive markers to determine body angles and distances.⁵

Recent studies have shown that the Microsoft Kinect system is capable of generating a 3-dimensional (3D) human body model with accuracy comparable to more expensive and complex scanning technologies.^{1,6}

This study aimed to evaluate children presenting with respiratory obstruction because of adenoid hypertrophy. Specifically, comparisons were made among children who underwent early adenoidectomy, those with an indication for surgery that was not performed, and children with normal nasal breathing. The study assessed changes in respiratory patterns, craniofacial

morphologic development, head and neck posture, and overall body posture among these groups.

MATERIAL AND METHODS

The protocol of this study was approved by the Bezmialem Vakif University Clinical Research Ethics Committee (No. 6/16, March 20, 2019). Informed consent forms were obtained from the families of all the children participating in the study. This study was designed as a retrospective cross-sectional study. Although current clinical and radiographic evaluations were performed at a single time point, patient grouping was based on retrospective data, such as surgical history and the duration elapsed since adenoidectomy.

The patients included in the study groups were selected from patients diagnosed with adenoid vegetations who presented to the Department of Otorhinolaryngology at Bezmialem Vakif University Faculty of Medicine. The control group consists of patients who visited the Departments of Pedodontics and Orthodontics at Bezmialem Vakif University Faculty of Dentistry. Three distinct groups were included in the study. The first group (group 1) consists of patients diagnosed with adenoid hypertrophy who presented at a later stage and were planned for adenoidectomy. The second group (group 2) consists of patients with respiratory obstruction because of adenoid hypertrophy who underwent early surgery and have completed at least 3 years of postoperative follow-up. The patients in this group were retrospectively selected from the archive of the Department of Otorhinolaryngology, and they were invited back by their otolaryngologist for this study. The control group (group 3) consists of subjects with no pathology or systemic disease-causing respiratory obstruction, and who exhibit normal nasal breathing. Participants in the control group (group 3) were selected by an otolaryngologist after a clinical examination by an otorhinolaryngologist that confirmed the absence of any upper airway obstruction. In addition, subjects were required to have a Nasal Obstruction Symptom Evaluation (NOSE) score within the normal range and no respiratory complaints as reported by their parents. These criteria ensured both objective and subjective confirmation of normal nasal breathing among control group participants. The workflow for creating groups is shown in [Figure 1](#). The patients included in both the study and control groups were aged 6–10 years, with the mean ages of the groups being 7.90 ± 1.55 , 8.10 ± 1.47 , and 8.30 ± 1.39 for groups 1, 2, and 3, respectively.

A power analysis was conducted using gonial ratio measurements from a similar study⁷ with G*Power software (Heinrich Heine University, Düsseldorf, Germany).

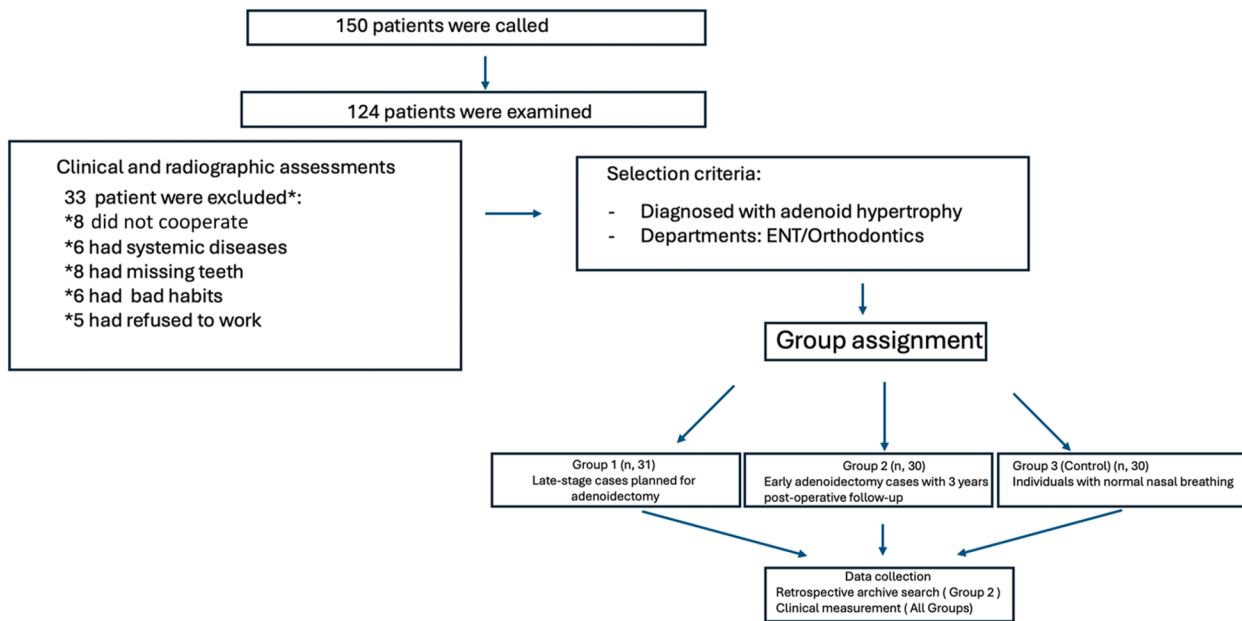


Fig 1. The workflow for creating groups.

The analysis revealed that a sample size of 20 patients per group would provide 85% power to detect significant differences, assuming an effect size of 0.4 and a significance level of $\alpha = 0.05$. To increase the power of the study, 31 subjects (13 females and 18 males) were included in group 1, 30 subjects (13 females and 17 males) in group 2, and 30 subjects (14 females and 16 males) in group 3.

Group 1 (nonsurgical obstruction group) included (1) children aged 6-10 years, (2) diagnosed with respiratory obstruction because of adenoid hypertrophy, (3) exhibiting chronic mouth breathing, (4) no history of adenoidectomy, (5) prepubertal stage according to hand-wrist radiographic analysis, and (6) no systemic diseases or syndromes.

Group 2 (adenoidectomy group) included (1) children aged 6-10 years, (2) a history of adenoidectomy performed between 3-6 years old, at least 3 years post-surgery, (3) a history of chronic mouth breathing before surgery, (4) prepubertal stage according to hand-wrist radiographic analysis, and (5) no systemic diseases or syndromes.

Group 3 (control group) included (1) children aged 6-10 years, (2) no signs of respiratory obstruction, (3) normal nasal breathing pattern, (4) no history of mouth breathing or adenoidectomy, (5) prepubertal stage according to hand-wrist radiographic analysis, and (6) no systemic diseases or syndromes.

Children with a history of previous or ongoing orthodontic treatment (especially slow or rapid maxillary

expansion) were excluded from the study to avoid potential influence on craniofacial development. Such patients were not eligible for inclusion in any of the 3 groups. Patients with temporomandibular joint problems, cleft lip or palate, orthodontic bad habits such as thumb or lip sucking, musculoskeletal disorders affecting posture, a history of posture correction treatment, and those undergoing pubertal growth spurts were also excluded.

All participants underwent routine clinical respiratory examination by the same otolaryngologist. The NOSE Scale⁸ was used for the clinical examination (Fig 2). This scale consists of 5 questions regarding the respiratory symptoms of the patients. In addition, a visual analog scale (VAS) assessment was performed, in which patients were asked to rate their respiratory quality on a scale from 0 to 10. A value of 0 was considered the “worst,” and a value of 10 the “best.” Subsequently, respiratory patterns were evaluated using the peak nasal inspiratory flow (PNIF) meter, which provides quantitative data on respiration. Patients were instructed to take a sharp breath through their nose while standing in an upright position, and 3 measurements were recorded, with the highest value being noted.

After respiratory examination, subjects from all groups were referred to the Department of Physical Medicine and Rehabilitation at Bezmi Alem Vakif University Faculty of Medicine for posture assessment. The analysis was conducted by the same physician using a 3D motion capture system equipped with Microsoft

Nasal Obstruction Symptom Evaluation (NOSE) Instrument

→ **To the Patient** Please help us to better understand the impact of nasal obstruction on your quality of life by **completing the following survey**. Thank You!

Over the past 1 month, how much of a problem were the following conditions for you?

Please circle the most correct response

	<i>Not a problem</i>	<i>Very mild problem</i>	<i>Moderate problem</i>	<i>Fairly bad problem</i>	<i>Severe problem</i>
1. Nasal congestion or stuffiness	0	1	2	3	4
2. Nasal blockage or obstruction	0	1	2	3	4
3. Trouble breathing through my nose	0	1	2	3	4
4. Trouble sleeping	0	1	2	3	4
5. Unable to get enough air through my nose during exercise or exertion	0	1	2	3	4

Fig 2. NOSE scale.

Kinect sensors. Using these sensors, posture analysis was performed via the “depth camera” on the sensor, without any invasive or harmful procedures for the patients.

The software determines the position and spatial orientation of joints. The Kinect system tracks 25 anatomic reference points on the body, which are shown in [Figure 3](#). The device is capable of measuring distances between 0.5–4.5 m. Quantitative data on head-neck alignment and overall body posture were obtained from both frontal and lateral views using the Becure software (Becureglobal, Mannheim, Germany), which was integrated with the Kinect system.

A comprehensive orthodontic clinical examination was performed on the patients included in the study, and then routine orthodontic radiographic records (panoramic, lateral cephalometric, posteroanterior head x-rays, and hand-wrist x-rays), extraoral-intraoral photographs, and dental casts were obtained. All radiographic records were acquired using the same device (Planmeca ProMax, Helsinki, Finland) and with the same standardized method. All radiographs (lateral cephalometric, posteroanterior, and hand-wrist) were obtained as part of routine orthodontic diagnostic protocols in patients with clear treatment indications. No additional radiographs were acquired solely for research purposes.

All cephalograms were traced and analyzed by the same researcher using the NemoCeph software version 10.4.2 (Software Nemetec, SL, Madrid, Spain). The evaluated measurements are presented in [Figure 4, A-E](#).

Dental impressions were taken from both maxillary and mandibular arches using Lascod Kromopan (Lascod SpA, Florence, Italy) alginate impression material using

impression trays, and plaster models were obtained by pouring hard dental stone onto the measurements taken. The measurements on the model were performed by the same researcher for each group using a digital caliper. Maxillary and mandibular intercanine widths were defined as the distance between the cusp tips of the right and left canines, whereas intermolar widths were defined as the distance between the most palatal (maxillary) and lingual (mandibular) gingival points on the right and left first molars.

Statistical analysis

The data were analyzed using the SPSS software (version 27; IBM, Armonk, NY). Intraexaminer reliability was assessed by reevaluating 5 randomly selected lateral cephalometric radiographs from each group after a 4-week interval. Bland-Altman plots and the intraclass correlation coefficient (ICC) were used to assess agreement and determine the reliability of the measurements. The normality of data distribution was tested using the Shapiro-Wilk test. For group comparisons, independent samples *t* test, 1-way analysis of variance, and Kruskal-Wallis tests with Bonferroni-adjusted post hoc analyses were employed. $P < 0.05$ was considered statistically significant.

RESULTS

The comparison of demographic characteristics of participants across the study groups is presented in [Table 1](#). The results of the ICC analysis conducted to assess intraexaminer reliability indicated a high level

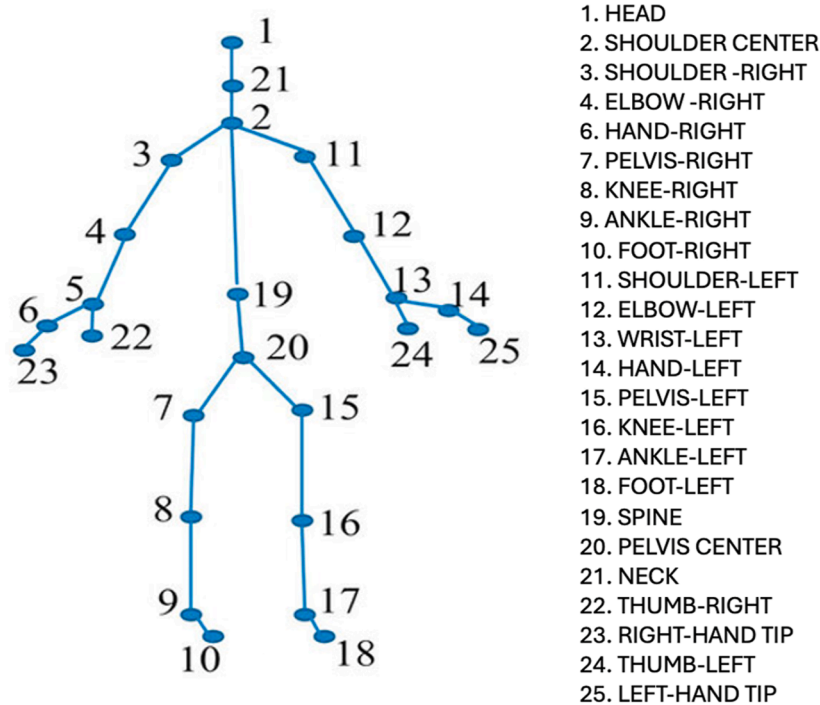


Fig 3. Points used in posture analysis.

of agreement between the repeated measurements, with a mean ICC value of 0.93.

Statistically significant difference was observed between groups 1 and 2, as well as between groups 1 and 3 across all parameters of the NOSE scale, PNIF measurements, and VAS evaluation ($P < 0.05$; Table II). Correlation analysis revealed a significant negative correlation between the NOSE scale and PNIF and VAS scores. In contrast, a significant positive correlation was identified between PNIF and VAS scores ($P < 0.05$; Table III).

No statistically significant differences were observed among the groups in any of the postural measurements ($P > 0.05$; Table IV). In addition, no significant correlations were found between the postural evaluation parameters and the respiratory parameters ($P > 0.05$; Table III).

Statistically significant differences were observed among the groups in the postcephalometric parameters: SNA°, ANB°, FMA°, Nasionperp-Pg (mm), PP-SN°, anterior facial height, posterior facial height, Go-Me (mm), U1-PP (mm), L1-NB°, E-upper lip (mm), E-lower lip (mm), Co-A (mm), mandibular length (Co-Gn) (mm), anterior cranial base (S-N) (mm) ($P < 0.05$, Tables V and VI).

SNA (°), ANB (°), y-axis (°), FMA (°), and E-upper lip (mm) values showed significant positive correlations with the NOSE scale and significant negative

correlations with PNIF and VAS scores. ($P < 0.05$; Table III). A significant negative correlation was observed between the NOSE scale and PP-SN (°), whereas significant positive correlations were found between PP-SN (°) and both PNIF and VAS scores ($P < 0.05$; Table III).

Posteroanterior cephalometric analyses revealed a statistically significant difference only in intergonial width between the groups ($P < 0.05$; Table VII). Furthermore, intergonial and interzygomatic widths were significantly correlated with both the NOSE scale and PNIF. A significant positive correlation was also observed between mandibular corpus length and both PNIF and VAS ($P < 0.05$; Table III).

No statistically significant differences were observed among the groups in dental cast measurements, except for intercanine width ($P < 0.05$; Table VIII). Correlation analysis revealed no significant associations among dental cast parameters and the NOSE scale, PNIF, and VAS values ($P > 0.05$; Table III).

DISCUSSION

Craniofacial structures reach approximately 60% of their adult size by 4 years old and 90% by 12 years old.⁹ The hypertrophy of pharyngeal lymphoid tissues during childhood is widely recognized as one of the main contributors to mouth breathing.¹⁰ Handelman

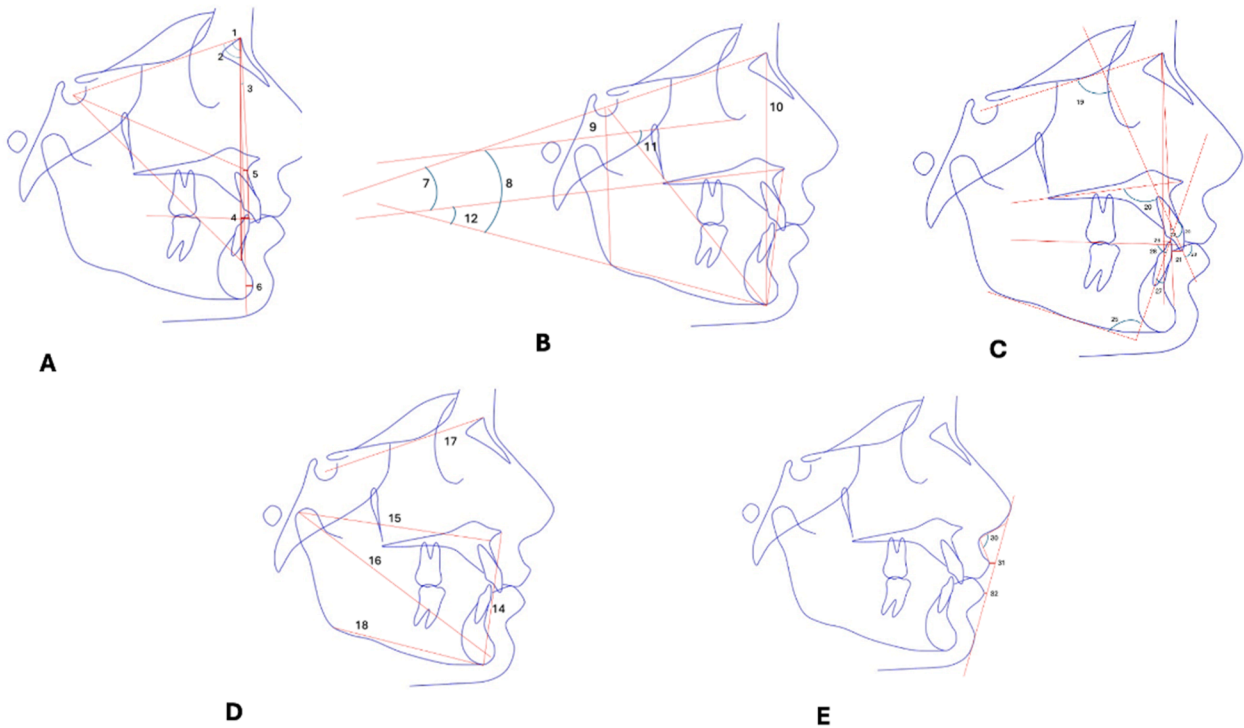


Fig 4. Cephalometric variables: **A**, 1. SNA ($^{\circ}$); 2. SNB ($^{\circ}$); 3. ANB ($^{\circ}$); 4. Wits analysis; 5; A-NaPerp (mm); 6. Pg-NaPerp (mm); **B**, 7. Mp-SN ($^{\circ}$); 8. FMA ($^{\circ}$); 9/10. S-Go/N-Me ($^{\circ}$); 11. y-axis ($^{\circ}$); 12. Mx-Md ($^{\circ}$); **C**, 14. ANS-Me (mm); 15. Co-A (mm); 16. Co-Gn (mm); 17. S-N (mm); 18. Go-Me (mm); **D**, 19. U1-SN ($^{\circ}$); 20. U1-PP ($^{\circ}$); 21. U1-NA (mm); 22. U1-NA ($^{\circ}$); 23. U1-OP ($^{\circ}$); 25. IMPA ($^{\circ}$); 26. L1-NB (mm); 27. L1-NB ($^{\circ}$); 28. L1-OP ($^{\circ}$); 29. U1-L1 ($^{\circ}$); (E) 30. Nasolabial angle ($^{\circ}$); 31. E-upper lip (mm); 32. E-Lower lip (mm).

Table I. Comparison of demographic data among groups

Variables	Group 1		Group 2		Group 3		P value
	Min/Max, n	Median, %	Min/Max, n	Median, %	Min/Max, n	Median, %	
Age, y	6-10	8	6-10	8	6.5-10	8	0.57
Gender							0.71
Female	13	41.9	13	43.3	14	46.7	
Male	18	58.1	17	56.7	16	53.3	

Note. Chi-square test was used for gender, whereas Kruskal-Wallis test with Bonferroni correction was applied for age. *Min*, minimum; *Max*, maximum.

and Osborne¹¹ reported that adenoid tissue hypertrophy is most commonly observed during 2 key developmental periods, around 4 and 8 years old. These lymphoid tissues typically reach their maximum size between 4-10 years old, and tend to regress after the pubertal growth spurt.¹² Therefore, this study focused on children aged 6-10 years, corresponding to the second peak of adenoid hypertrophy.¹³

In this study, SNA values were significantly higher in the group that had not undergone adenoidectomy, whereas PP-SN values were significantly lower in group

1. Mattar et al¹⁴ reported a significant increase in SNA values both preoperatively and 28 months postoperatively in children aged 3-6 years with mouth breathing, although no significant change in PP-SN values was observed. The discrepancies between our findings and those of Mattar et al¹⁴ may stem from differences in age distribution, follow-up duration, and methodological approaches.

In our sample, persistent mouth breathing in patients who had not undergone adenoidectomy appeared to be associated with a tendency toward

Table II. Comparison of the respiratory parameters among groups

	Group 1			Group 2			Group 3			P value	Post-hoc		
	Min	Max	Median	Min	Max	Median	Min	Max	Median		1-2	1-3	2-3
Q1	0	3	2	0	3	4.5	0	2	1	<0.001*	<0.001	<0.001	NS
Q2	1	4	3	0	4	1	0	2	1	<0.001*	<0.001	<0.001	NS
Q3	0	4	3	0	4	0	0	3	0	<0.001*	<0.001	<0.001	NS
Q4	0	4	2	0	4	1	0	3	0	<0.001*	0.009	<0.001	NS
Q5	0	4	2	0	3	1	0	3	0	<0.001*	0.002	0.01	NS
Total	4	19	11	0	17	4	0	10	2.5	<0.001*	<0.001	<0.001	NS
VAS	1	9	4	1	9	8	0	10	8	<0.001*	<0.001	<0.001	NS
PNIF	30	65	45	40	100	65	45	80	60	<0.001*	<0.001	<0.001	NS

Note. Kruskal-Wallis test with Bonferroni correction was used for statistical analysis. The asterisk indicates statistical significance. Q, question; Total, the total sum of the scores given to the questions; *Min*, minimum; *Max*, maximum; *NS*, not significant.

skeletal Class II maxillary patterns, a decrease in the maxillary plane angle, and increased anterior maxillary rotation. However, given the relatively small sample size and the potential influence of uncontrolled variables such as baseline malocclusion and individual growth variation, these statistically significant findings should be interpreted with caution, as they may not necessarily reflect clinically meaningful differences.

Furthermore, the FMA angle was significantly elevated in subjects with mouth breathing, which is consistent with previous literature.^{15,16} Correlation analysis revealed that respiratory function worsened as ANB and y-axis angles increased, suggesting a tendency toward vertical growth and Class II skeletal patterns in patients with chronic mouth breathing. In addition, a reduction in posterior facial height was documented among mouth-breathing patients, aligning with findings by Sousa et al,¹⁷ who also reported diminished posterior facial height in this population.

Recent evidence further supports the association between mouth breathing and altered vertical growth patterns. A systematic review by Zhao et al¹⁸ found that children with mouth-breathing habits presented with significantly increased mandibular plane angles and greater anterior facial height.

Consistently, Zheng et al¹⁹ also reported that vertical skeletal dimensions were more pronounced in mouth-breathing subjects compared with nasal breathers.

These cumulative findings reinforce the concept that impaired nasal respiration during growth may alter vertical craniofacial development trajectories. An increase in total anterior facial height was also noted among children who continued mouth breathing and did not undergo adenoidectomy. This finding is consistent with the results of Bresolin et al²⁰ and Ucar et al,²⁰ both of whom reported increased vertical facial dimensions in mouth-breathing subjects.

Corpus length (Go-Me) was significantly smaller in group 1, the mouth-breathing group, compared with the other groups. This finding aligns with those of Behl-felt,²¹ who reported shorter mandibular lengths in subjects with adenoid hypertrophy.

Group 1 also presented significantly reduced intergonial distance values. Although Ceylan et al²² did not report significant differences in interzygomatic, intergonial, or interjugular distances between mouth-breathing and nasal-breathing subjects, both Ricketts²³ and Linder Aronson²⁴ observed a reduction in facial width associated with mouth breathing. In our study, group 1 also exhibited significantly mandibular intercanine width. Although a reduction in intermolar width was observed, it did not reach statistical significance. These findings are consistent with those of Vieira et al,²⁵ who reported significant intercanine, but not intermolar, differences in a comparative study of preoperative and postoperative adenoidectomy casts in children.

Similarly, recent reviews have emphasized the relationship among oral breathing, adenoid hypertrophy, and maxillofacial development. Lin et al²⁶ highlighted that chronic mouth breathing can negatively impact dentofacial growth, leading to increased facial height and altered transverse dimensions. In addition, Ma et al²⁷ confirmed that adenoid hypertrophy and prolonged oral breathing are associated with sagittal, vertical, and transverse maxillofacial changes.

Costa et al²⁸ noted that orthodontists were able to successfully diagnose mouth breathing in only 17.0%-31.3% of patients, highlighting the importance of interdisciplinary evaluation, particularly collaboration with otolaryngologists, when signs of airway obstruction are present. In this study, in addition to clinical and respiratory assessments, the PNIF meter was used as an objective diagnostic tool. PNIF measures the peak flow rate during nasal inhalation and has been

Table III. Correlation analysis among respiratory patterns and dental, skeletal parameters, and posture

Variables	NOSE scale		PNIF		VAS	
	r	P value	r	P value	r	P value
SNA (°)	0.245	0.040*	-0.322	0.008*	-0.304	0.010*
SNB (°)	0.169	0.170	-0.228	0.040*	-0.181	0.140
ANB (°)	0.264	0.010*	-0.187	0.070	-0.283	0.006*
Witts (mm)	-0.110	0.380	-0.03	0.790	-0.020	0.840
PP-SN (°)	-0.328	0.007*	0.379	0.002*	0.318	0.009*
y-axis (°)	0.253	0.016*	-0.216	0.004*	-0.205	0.045*
Anterior facial height	0.035	0.780	0.139	0.260	0.070	0.540
Posterior facial height	-0.166	0.117	0.201	0.056	0.201	0.227
Facial height (%)	-0.090	0.460	-0.029	0.810	-0.009	0.940
FMA (°)	0.287	0.006*	-0.195	0.044*	-0.227	0.031
Anterior cranial base	0.200	0.090	-0.140	0.250	0.030	0.790
Go-Me (mm)	-0.030	0.750	0.070	0.550	0.002	0.980
U1-SN (°)	-0.140	0.240	0.100	0.410	0.110	0.350
IMPA (°)	-0.150	0.210	0.120	0.300	0.120	0.330
L1-NB (°)	0.080	0.500	-0.020	0.850	-0.110	0.370
U1-L1 (°)	0.004	0.970	-0.070	0.550	-0.030	0.800
Nasolabial angle (°)	-0.010	0.930	-0.040	0.730	-0.090	0.450
Upper lip (mm)	0.307	0.003	-0.259	0.013*	-0.368	<0.001*
Lower lip (mm)	0.161	0.128	-0.236	0.054	-0.156	0.140
Overjet (mm)	-0.010	0.920	-0.040	0.730	0.160	0.770
Overbite (mm)	-0.060	0.610	-0.090	0.460	0.010	0.990
Intergonial distance	-0.249*	0.010*	0.300*	0.004*	0.177	0.093
Interjugal distance	0.035	0.780	-0.040	0.750	0.006	0.960
Interzygomatic distance	-0.123	0.244	0.296*	0.004*	0.070	0.508
Right ramus length	-0.067	0.526	0.028	0.790	0.088	0.404
Left ramus length	0.039	0.712	0.075	0.479	0.043	0.688
Right corpus length	-0.165	0.118	0.235*	0.025*	0.292	0.005*
Left corpus length	-0.129	0.110	0.311*	0.003*	0.216*	0.039*
UR6-UL6 (mm)	0.020	0.860	0.130	0.290	0.030	0.770
LR6-LL6 (mm)	-0.030	0.980	-0.020	0.590	-0.020	0.820
UR3-UL3 (mm)	-0.010	0.870	0.150	0.220	0.170	0.150
LR3-LL3 (mm)	-0.010	0.990	0.140	0.250	0.010	0.920
A-head (°)	0.020	0.810	-0.120	0.330	-0.090	0.450
A-shoulder (°)	0.030	0.780	-0.040	0.750	0.006	0.960
A-Pelvis (°)	0.020	0.860	0.130	0.290	0.030	0.770
R-head (°)	0.110	0.340	-0.020	0.590	-0.020	0.820
R-shoulder (°)	-0.200	0.100	0.170	0.150	0.120	0.300
R-pelvis (°)	-0.080	0.500	0.080	0.510	-0.010	0.930

Note. Spearman correlation analysis was used in statistical analysis, correlation coefficient. The asterisk indicates statistical significance.

increasingly adopted in European clinical settings because of its affordability, portability, and ease of use.²⁹

Given the importance of reliable respiratory assessment tools in pediatric populations, it is crucial to employ both subjective and objective methods when evaluating nasal obstruction. The NOSE scale, a validated and widely used subjective measure, has been shown to reliably assess nasal-breathing difficulties in children. Kawai et al³⁰ confirmed that the NOSE scale provides consistent and clinically meaningful evaluations, supporting its applicability in pediatric practice. In this study, the NOSE scale was used alongside objective respiratory assessments to ensure a standardized

and comprehensive evaluation of nasal breathing. Mozanica et al³¹ reported a strong correlation between NOSE and VAS scores, further supporting the scale's reliability. Similarly, Cengiz et al³² found that PNIF values significantly improved 3 months after adenoidectomy and were higher in the control group than in mouth-breathing patients. Consistent with these findings, our results revealed significantly lower PNIF values in group 1. Furthermore, negative correlations among PNIF, NOSE, and VAS scores suggest consistency between subjective and objective respiratory assessments. These observations support prior studies confirming the reliability of NOSE and VAS in evaluating nasal airflow obstruction.³¹

Table IV. Comparison of posture parameters among groups

Variables	Group 1			Group 2			Group 3			P value
	Min	Max	Median	Min	Max	Median	Min	Max	Median	
A-head	0.00	9.30	4.25	0.80	9.30	1.65	0.00	2.0	1	0.64
A-shoulder	0.00	4.60	1.68	0.10	7.40	1.60	0.00	2.0	1	0.95
A-hand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.0	0	1.00
A-pelvis	0.00	4.40	1.10	0.10	4.90	1.45	0.00	3.0	0	0.11
R-head	2.70	46.50	2.65	2.70	46.50	20.95	0.00	3.0	0	0.17
R-shoulder	0.00	9.30	2.40	0.00	10.80	2.70	0.00	10.0	2.5	0.67
R-pelvis	0.00	8.60	2.40	0.00	10.00	2.65	0.00	10.0	8	0.53

Note. The Kruskal-Wallis test was with Bonferroni correction used for statistical analysis.
Min, minimum; *Max*, maximum.

Table V. Comparison of normally distributed cephalometric parameters among groups

Variables	Group 1	Group 2	Group 3	P value	Post-hoc		
					1-2	1-3	2-3
SNA (°)	81.87 ± 2.83	79.66 ± 2.59	79.63 ± 3.11	0.003*	0.01	0.009	NS
SNB (°)	76.61 ± 2.46	75.38 ± 2.36	76.12 ± 3.80	0.27	NS	NS	NS
Wits (mm)	0.25 ± 3.23	0.39 ± 3.96	-0.07 ± 5.27	0.095	NS	NS	NS
N-A (mm)	-0.32 ± 2.61	-0.75 ± 2.41	-0.13 ± 2.17	0.54	NS	NS	NS
Maxillary-mandibular angle	29.19 ± 3.95	27.50 ± 4.37	27.74 ± 4.92	0.094	NS	NS	NS
Facial height (S-Go/N-Me) (%)	62.83 ± 3.00	62.92 ± 3.60	63.76 ± 4.58	0.57	NS	NS	NS
ANS-Me (mm)	65.46 ± 5.41	66.38 ± 5.62	63.77 ± 6.20	0.20	NS	NS	NS
Go-Me (mm)	64.29 ± 4.64	67.27 ± 3.30	65.46 ± 5.18	0.03*	0.03	NS	NS
L1-NB (°)	25.19 ± 6.26	26.44 ± 4.95	21.58 ± 7.93	0.01*	NS	NS	0.01
L1-OP (°)	72.32 ± 15.96	68.02 ± 7.25	71.19 ± 8.73	0.31	NS	NS	NS
U1-L1 (°)	132.88 ± 10.74	129.78 ± 8.92	135.71 ± 11.71	0.09	NS	NS	NS
Nasolabial angle	110.41 ± 11.76	105.85 ± 10.53	111.49 ± 12.42	0.14	NS	NS	NS
E-lower lip (mm)	-0.36 ± 2.88	-0.25 ± 1.81	-1.81 ± 2.56	0.02*	NS	NS	0.002

Note. Values are presented as mean ± standard deviation. One-way analysis of variance test with Bonferroni correction was used for statistical analysis. The asterisk indicates statistical significance.
NS, not significant.

Numerous studies have investigated the relationship between mouth breathing and head and whole-body posture.^{33,34} Although clinical decisions often rely on this association, the literature regarding the postural impact of mouth breathing in children remains limited and inconclusive.³⁵ In our study, postural analysis was conducted using a 3D motion capture system based on Microsoft Kinect sensors.

The first-generation Kinect sensor (Kinect v1), released in 2010 for the Xbox 360, integrates a video camera, infrared transmitter, and depth sensor to generate 3D body models.³⁶ The depth sensor collects spatial data, allowing the system to render body posture and movement in real time. Recent validation studies have demonstrated that Kinect-based systems offer a level of body mapping accuracy comparable to that of more complex and expensive 3D scanning technologies.⁶ Compared with traditional optoelectronic or

electromagnetic motion capture systems, the Kinect sensor offers portability, cost-effectiveness, and does not require reflective markers or skin preparation.³⁶

It has been successfully validated in various fields, including physical therapy and biomechanics.^{6,37} In this study, this system was used to assess postural changes, representing a novel and accessible approach for pediatric postural analysis.

Previous studies have indicated that children with adenoid-related airway obstruction often develop compensatory craniocervical postural adaptations, such as increased head tilt, to maintain airway patency.^{38,39} Okuro et al⁴⁰ found that children aged 8-11 years with mouth breathing exhibited significantly greater cervical postural deviations compared with nasal breathers. Similarly, a larger study involving 430 children found a higher prevalence of postural abnormalities among mouth-breathing patients.

Table VI. Comparison of non-normally distributed cephalometric parameters among groups

Variables	Group 1			Group 2			Group 3			P value	Post-hoc		
	Min	Max	Median	Min	Max	Median	Min	Max	Median		1-2	1-3	2-3
ANB (°)	1.0	7.5	5.8	-3.3	7.7	4.5	-3.3	10.8	2.5	0.023*	NS	0.006	NS
Nasionperp-Pg (mm)	-23.3	62.0	-5.6	-26.5	2.7	-8.6	-18.1	15.1	-2.4	0.015*	NS	0.023	0.007
y-axis angle (°)	9.2	63.9	60.3	41.1	64.6	59.6	50.3	64.5	59.1	0.314	NS	NS	NS
PP-SN (°)	3.7	39.3	7.2	5.1	12.7	8.5	4.4	39.0	9.9	0.004*	NS	0.001	NS
FMA (°)	15.6	105.1	29.8	16.9	34.5	26.5	13.8	36.5	26.1	0.028*	0.032	0.01	NS
Anterior facial height (mm)	125.2	75.3	111.4	98.0	134.3	74.0	90.5	125.4	113.6	0.048*	0.014	NS	NS
Posterior facial height (mm)	59.6	78.2	70.5	64.1	116	74.0	60.8	78.0	74.6	0.017*	0.014	0.013	NS
Co-A (mm)	70.3	98.0	103.9	79.0	88.8	84.3	68.4	88.3	81.8	0.028*	NS	NS	0.008
Co-Gn (mm)	67.1	116.1	103.9	97.1	120.9	106.5	79.2	120.3	105.6	0.041*	0.012	NS	NS
Anterior cranial base (mm)	59.0	73.9	69.6	69.3	77.6	71.8	57.3	71.8	69.3	0.013*	0.038	NS	0.004
U1-SN (°)	84.6	113.3	97.3	90.4	110.2	98.4	74.3	110.2	101.0	0.372	NS	NS	NS
U1-PP (mm)	94.4	117.1	105.4	100.2	120.7	107.5	11.7	120.7	109.0	0.040*	NS	0.013	NS
U1-Na (mm)	0.2	5.3	1.9	0.1	7.5	1.8	0	7.8	2.7	0.172	NS	NS	NS
U1-OP (°)	52.5	74.6	61.9	48.1	74.1	59.6	48.1	70.8	59.5	0.436	NS	NS	NS
L1-A/Pg (mm)	-4.3	5.3	2.29	-2.8	11.4	2.5	-4.3	77.3	1.8	0.715	NS	NS	NS
IMPA (°)	77	101	91.7	83.3	107.9	93.45	73.6	103.5	93.1	0.180	NS	NS	NS
L1-NB (mm)	0.4	9.5	4.2	0.4	8.6	5.45	0.1	10.5	3.5	0.068	NS	NS	NS
E-upper lip (mm)	-5.3	4.2	-1.1	-6.8	3.3	-1.3	-6.6	3.8	-2.9	0.010*	NS	0.002	NS
Overjet (mm)	-1.4	9.2	3.0	-6.1	7.0	3.6	-2.8	9.2	3.1	0.999	NS	NS	NS
Overbite (mm)	-3.0	6.0	1.0	-5.7	4.6	1.65	-1.6	6.0	2.0	0.274	NS	NS	NS

Note. Kruskal-Wallis analysis was used for statistical analysis. Post-hoc Bonferroni test was used for pairwise comparisons. The asterisk indicates statistical significance.

Min, minimum; Max, maximum; NS, not significant.

Table VII. Comparison of posteroanterior cephalometric parameters among groups

Variables	Group 1			Group 2			Group 3			P value	Post-hoc		
	Min	Max	Median	Min	Max	Median	Min	Max	Median		1-2	1-3	2-3
Intergonial distance	59.80	73.50	66.60	62.60	76.40	70.70	65.00	76.00	68.70	0.001*	0.001	0.001	NS
Interjugular distance	49.10	64.00	54.00	50.60	61.20	56.30	50.60	61.00	55.80	0.139	NS	NS	NS
Interzygomatic distance	127.80	150.20	139.40	110.90	153.70	141.40	131.00	152.80	142.40	0.119	NS	NS	NS
Right-left ramus length difference	0.00	2.30	0.80	0.10	3.80	0.65	0.20	2.00	1.00	0.333	NS	NS	NS
Right-left corpus length difference	0.00	2.40	0.90	0.00	3.20	0.50	0.15	2.20	1.00	0.073	NS	NS	NS

Note. The Kruskal-Wallis analysis test with Bonferroni correction was used for statistical analysis. The asterisk indicates statistical significance.

Min, minimum; Max, maximum; NS, not significant.

As a result of forward head posture, these children were shown to exhibit medial rotation of the shoulders, elevation of the scapula, depression in the anterior thoracic region, external rotation of the knees, and flattened feet because of the forward displacement of the entire body.⁴¹ In this study, although angular deviations were detected in the head and neck region across all groups, no statistically significant differences in postural changes were observed among the groups. Furthermore, no significant correlation was found between postural changes and respiratory parameters. In a study of 59 patients aged 8-11 years, Bolzan et al³³ reported that respiratory patterns did not affect

postural relationships. Chambi-Rocha et al,⁴² in their clinical and radiographic evaluation of 98 patients aged 7-16 years, found no differences in posture between mouth breathers and nasal breathers. Kirkwood et al,⁴³ in their 2018 systematic review, concluded that there was low-level evidence supporting an association between mouth breathing and postural deviations in children aged 5-14 years. However, it should be noted that recent high-quality studies directly examining the relationship between mouth breathing and postural deviations in pediatric populations appear to be limited.

As McEvoy and Grimmer⁴⁴ suggested, postural changes during childhood often reflect adaptations to

Table VIII. Comparison of dental cast measurements among groups

	Group 1			Group 2			Group 3			Post-hoc			
	Min	Max	Median	Min	Max	Median	Min	Max	Median	P value	1-2	1-3	2-3
UR6-UL6	30.20	38.60	33.40	30.50	41.30	35.20	26.90	38.40	35.100	0.08	NS	NS	NS
LR6-LL6	28.30	39.40	34.50	27.60	40.50	33.80	26.40	37.70	33.80	0.91	NS	NS	NS
UR3-UL3	21.20	35.00	24.40	21.40	30.20	26.50	21.00	28.00	24.90	0.04*	0.01	NS	0.04
LR3-LL3	18.60	28.00	20.70	17.80	25.40	21.30	18.30	26.3	22.20	0.09*	NS	0.001	NS

Note. The statistical analysis used was the Kruskal-Wallis test with Bonferroni correction. The asterisk indicates statistical significance.

Min, minimum; Max, maximum; UR6-UL6, maxillary intermolar width; LR6-LL6, mandibular intermolar width; UR3-UL3, maxillary intercanine width; LR3-LL3, mandibular intercanine width; NS, not significant.

rapid changes in body proportions, particularly between 7–12 years old. Penha et al⁴⁵ similarly reported a high incidence of postural compensation in healthy children within this age range. Given that this study population fell within the same developmental window, the absence of statistically significant postural differences among groups may be attributed to ongoing musculoskeletal maturation. Additional factors such as gender, body mass, height, coordination, and the presence of musculoskeletal discomfort may have further contributed to the variability in postural assessments.

The main limitation of this study is the relatively small sample size. A larger sample size would help enhance the reliability of the results. Another limitation is the retrospective cross-sectional design of the study. Because of ethical concerns, a longitudinal study was not feasible, as mouth breathing requires treatment and intervention once diagnosed. Postural changes can be influenced by various factors in a person's life, which may affect the results when evaluating the relationship between mouth breathing and posture. Nevertheless, a major strength of the study is the comprehensive evaluation, combining clinical, respiratory, orthodontic, and postural assessments using standardized and validated tools. This multidimensional approach provides a broader perspective on the effects of mouth breathing.

Although care was taken in participant selection, certain environmental factors—such as allergic conditions, seasonal changes, socioeconomic differences, and sleep-related breathing habits—were not controlled and may have influenced the findings. In addition, to eliminate the potential bias of prior treatment, children with any history of previous or ongoing orthodontic intervention were excluded.

Furthermore, although several cephalometric parameters (eg, SNA°, SNB°, and FMA°) showed statistically significant differences among groups, these results may not necessarily reflect clinically significant effects because of individual biological variability and the relatively modest sample size. Therefore, the findings should be interpreted with caution, considering

the distinction between statistical and clinical significance and the possible influence of uncontrolled variables such as baseline malocclusion type or racial/ethnic background.

Despite these limitations, the findings suggest that persistent mouth breathing may be indicative of underlying developmental issues.

CONCLUSIONS

1. Measurements obtained using the PNIF meter were consistent with the scores on the NOSE scale and the VAS, both of which assess nasal-breathing quality. Therefore, a detailed respiratory anamnesis when combined with objective methods appears to be valid and reliable.
2. In patients with an indication for adenoidectomy who did not undergo surgery, limited nasal breathing was observed to persist over time, suggesting that spontaneous improvement with growth may not always occur.
3. Among patients requiring adenoidectomy but who were not operated on, an increase in sagittal maxillary growth was observed, accompanied by counterclockwise rotation of the maxilla. In this group, an increase in the FMA angle and a decrease in posterior facial height and reduced mandibular width, and corpus length were also observed.
4. Although intercanine width appeared to narrow in association with mouth breathing, the intermolar width was not significantly affected.
5. No statistically significant differences were observed in postural measurements among the analyzed groups.

In summary, children who underwent early adenoidectomy demonstrated respiratory, postural, and craniofacial characteristics that were more comparable to those with normal nasal breathing, whereas children who did not undergo surgery showed patterns that may be associated with persistent mouth breathing.

However, it should be emphasized that the success criterion for adenoidectomy is not solely the removal of airway obstruction but also the transition to functional nasal breathing. Therefore, the potential for continued mouth breathing related to habitual factors, close collaboration between ear, nose, and throat specialists and orthodontists is essential for the management and long-term follow-up of these patients.

AUTHOR CREDIT STATEMENT

Meral Gurkan contributed to conceptualization, data curation, investigation, methodology, validation, visualization, and manuscript review and editing; Elif Dilara Arslan contributed to conceptualization, formal analysis, investigation, methodology, supervision, validation, visualization, and manuscript review and editing; Erol Senturk contributed to conceptualization, investigation, methodology, supervision, and manuscript review and editing; Gokmen Kurt contributed to conceptualization, investigation, methodology, supervision, and manuscript review and editing; and Teoman Aydin contributed to conceptualization, investigation, methodology, supervision, and manuscript review and editing.

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