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Original Article

Gender-based Comparison of Pharyngeal Airway Between Class I and Class III Patients During MP3cap Growth Period

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Main Points

- The dimensions of the nasopharyngeal area were similar across different malocclusion groups and genders.
- The inferior pharyngeal space was larger in girls with Class III malocclusion compared to boys with the same condition.
- Girls displayed a more extensive head posture than boys in both Class I and Class III malocclusions.
- When planning orthodontic treatment during the growth and development period, it is important to consider the age, gender, and malocclusion characteristics in relation to the pharyngeal airway.

ABSTRACT

Objective: To compare the pharyngeal airway size and area between Class III patients exhibiting optimal vertical growth direction and Class I patients at the MP3cap stage, considering gender differences.

Methods: This retrospective study analyzed pre-treatment cephalograms of a total of 180 patients with Class I (45 girls, 45 boys) and Class III (maxilla or maxillo-mandibular origin) (45 girls, 45 boys) malocclusions. Linear and angular measurements were conducted on lateral cephalograms utilizing the GNU Image Manipulation Program (GIMP 2.10.18, NY, USA; https://www.gimp.org/). The pharyngeal airway areas were computed utilizing AUTOCAD (Autodesk 2018, San Rafael, CA, USA). The Independent Samples t-test and Mann-Whitney U test were employed for comparative analysis of variables across groups. The forward selection method was employed in conjunction with regression analysis.

Results: No significant differences were observed in the nasopharyngeal area (NA; mm^2) across the malocclusion groups and genders. In Class III girls, the oropharyngeal area (OA; mm^2), retroglossal (RG; mm^2) area, and superior pharyngeal space (SPS; mm) were significantly larger than those of Class III boys, and Class I girls ($p<0.05$). The inferior pharyngeal space (IPS; mm) was significantly larger in Class III girls compared to Class III boys ($p<0.05$). Girls with Class I/III malocclusions demonstrated a more pronounced head posture than boys ($p<0.05$).

Conclusion: The findings indicate the necessity of accounting for gender-specific variations in Class I and III patients, as well as evaluating pharyngeal airway characteristics in orthodontic diagnosis and treatment planning. In Class III girls, the OA and RG areas, as well as the superior and inferior pharyngeal spaces, were larger compared to Class III boys.

Keywords: Airway, Class I, Class III malocclusion, pharyngeal

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INTRODUCTION

The pharyngeal airway is a complex structure closely associated with the maxilla and mandible. The etiology of Class III malocclusion and the variability of the maxillomandibular sagittal relationship are associated with alterations in airway and breathing patterns.[1] In recent years, the number of studies evaluating the relationship between malocclusions and the pharyngeal airway has increased in the literature.[2,3] Although numerous studies have assessed the impact of various treatments for skeletal Class III malocclusion on the pharyngeal airway[4-7] there is a paucity of research examining the pharyngeal airway in untreated Class III patients. Furthermore, disparate findings have emerged, attributed to variations in age, gender, and methodological approaches among the studies.[2,3,8-11] Thus, it is essential to investigate the relationship between Class III malocclusion and the pharyngeal airway within homogeneous groups.

This study aimed to compare the pharyngeal airway size and area between Class III patients exhibiting optimal vertical growth and Class I patients during the MP3cap growth period, across both genders. The number of studies establishing pharyngeal airway normative values in Class I patients is limited, and current research frequently includes a small sample size and skeletal measurements.[12-14] Consequently, our secondary objective was to establish the normative values of airway dimensions in Class I subjects exhibiting optimal sagittal and vertical growth patterns, underscoring the necessity for additional research.

METHODS

This retrospective study examined the pre-treatment lateral cephalograms of 180 patients (90 boys and 90 girls) with Class I (45 girls, 45 boys) and Class III (45 girls, 45 boys) malocclusions, referred to the orthodontic clinic of the University. Parents of all participating children were informed, and the study protocol received approval from the Measurement and Evaluation Ethics Sub-Working Group of the Gazi University (approval no.: 2020-465, date: 08.09.2020). Informed consent forms were obtained from each patient.

Power analysis was performed utilizing G*Power 3.1.9.7 (University of Düsseldorf, Düsseldorf, Germany) to ascertain the necessary sample size for the skeletal Class I and III malocclusion groups. This study utilized data from analogous prior research as references for the ANB angle, nasopharyngeal airway area, and oropharyngeal airway area.[16] The sample size of 87 patients per group at α=0.05 provides a statistical power of 95% for this study; however, it was increased to 90 to achieve equal gender distribution. The inclusion criteria for the Class I group were established as follows: ANB angle ranging from 0 to 4°, SN/GoGn angle between 26 and 38°, MP3cap growth development period (the epiphysis of the middle phalanx of the third finger is equal to or wider than the metaphysis, with lateral sides exhibiting initial capping towards the metaphysis), and chronological age between 10 and 14 years. The inclusion criteria for the Class III group were: a negative ANB angle, a skeletal Class III anomaly originating from the maxilla or maxillo-mandibular region, Angle Class III malocclusion, an SN/GoGn angle ranging from 26° to 38°, anterior crossbite, MP3cap growth development period, and a chronological age between 10 and 14 years (Figure 1).

The study analyzed 11088 patients from the digital archive of the orthodontic department, excluding individuals with ANB angles exceeding 4°, SN/GoGn greater than 38°, SN/GoGN less than 26°, and those not in the MP3cap growth and development stage, as well as those exhibiting accelerated or retarded growth with a deviation of more than one year between chronological and skeletal ages. Furthermore, individuals with a prior history of orthodontic treatment, upper airway pathology, or oral respiration were excluded from the study. Patient selection for each malocclusion class and gender group was conducted using random number generation in Excel, yielding 45 randomly selected patients per group. Figure 1 illustrates the flow chart developed for patient selection criteria.

Lateral cephalograms were obtained under standardized conditions, with the head stabilized using a cephalostat, teeth in centric occlusion, and the Frankfort horizontal plane aligned parallel to the floor. Linear and angular measurements of lateral cephalograms were conducted by a single researcher utilizing the GNU Image Manipulation Program (GIMP 2.10.18, NY, USA; https://www.gimp.org/). Fifteen lateral cephalograms from each group were randomly selected, re-digitized, and recalculated by the same researcher two weeks later to assess the reliability of the method. The pharyngeal airway areas were calculated utilizing AUTOCAD (Autodesk 2018, San Rafael, CA, USA). Cephalometric radiographs were aligned based on a plane with a specified measurement in millimeters, after which the "Measure" command was utilized to select the corner points of the airway region for measurement purposes. Linear measurements and airway areas were ultimately compared across the groups (Figure 2, Table 1).

Statistical Analysis

Data analysis was conducted using IBM version 20.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was employed to assess normality. The statistical analysis utilized the Independent Samples t-test and the Mann-Whitney U test for comparing variables between groups. A significance level of $p<0.05$ was deemed statistically significant. A multiple linear regression analysis was conducted to identify cephalometric measurements that may influence pharyngeal airway measurements.

The multiple linear regression analysis utilized the "forward selection" method to select independent variables for inclusion in the model. Independent variables with a p-value less than 0.20 were deemed eligible for inclusion in the multiple linear regression model.

RESULTS

The measurements for each parameter were evaluated for reliability using the intra-class correlation coefficient, yielding statistically significant results (p<0.001), which indicates high reliability. The chronological ages of girls with skeletal Class I (137.2±9.1 months) and Class III (138.9±11.2 months) malocclusions were comparable. No significant differences were observed in the ages of boys with Class III (145.4±9.8 months) and Class I (143.8±9.4 months) malocclusions. The chronological and skeletal ages of boys with Class I malocclusions were significantly greater than those of girls with Class I malocclusions (p=0.001, p<0.001, respectively). The chronological and skeletal ages of the Class III boys were significantly higher than those of the Class III girls (p<0.01, p<0.001; respectively).

Comparisons Between Malocclusions

Boys with Class I malocclusion had higher Co-A and ANB values, and a smaller SNB angle than boys with Class III malocclusion (p<0.001). In Class I boys, AA'-Pm' and AA-PNS dimensions were found to be significantly larger than those in Class III boys (p<0.05).

The Co-A length, SNA, and ANB angles were significantly higher in skeletal Class I girls compared to Class III girls (p<0.001, p<0.01, p<0.001; respectively). The SNB angle and Co-Gn distance were observed to be smaller in Class I girls compared to Class III girls (p<0.001, p<0.05, respectively). The oropharyngeal area (OA) and retroglossal (RG) area were significantly smaller in skeletal Class I girls compared to Class III girls (p<0.001, p=0.001; respectively). Class III girls exhibited greater nasopharyngeal height (S-PNS) and upper airway

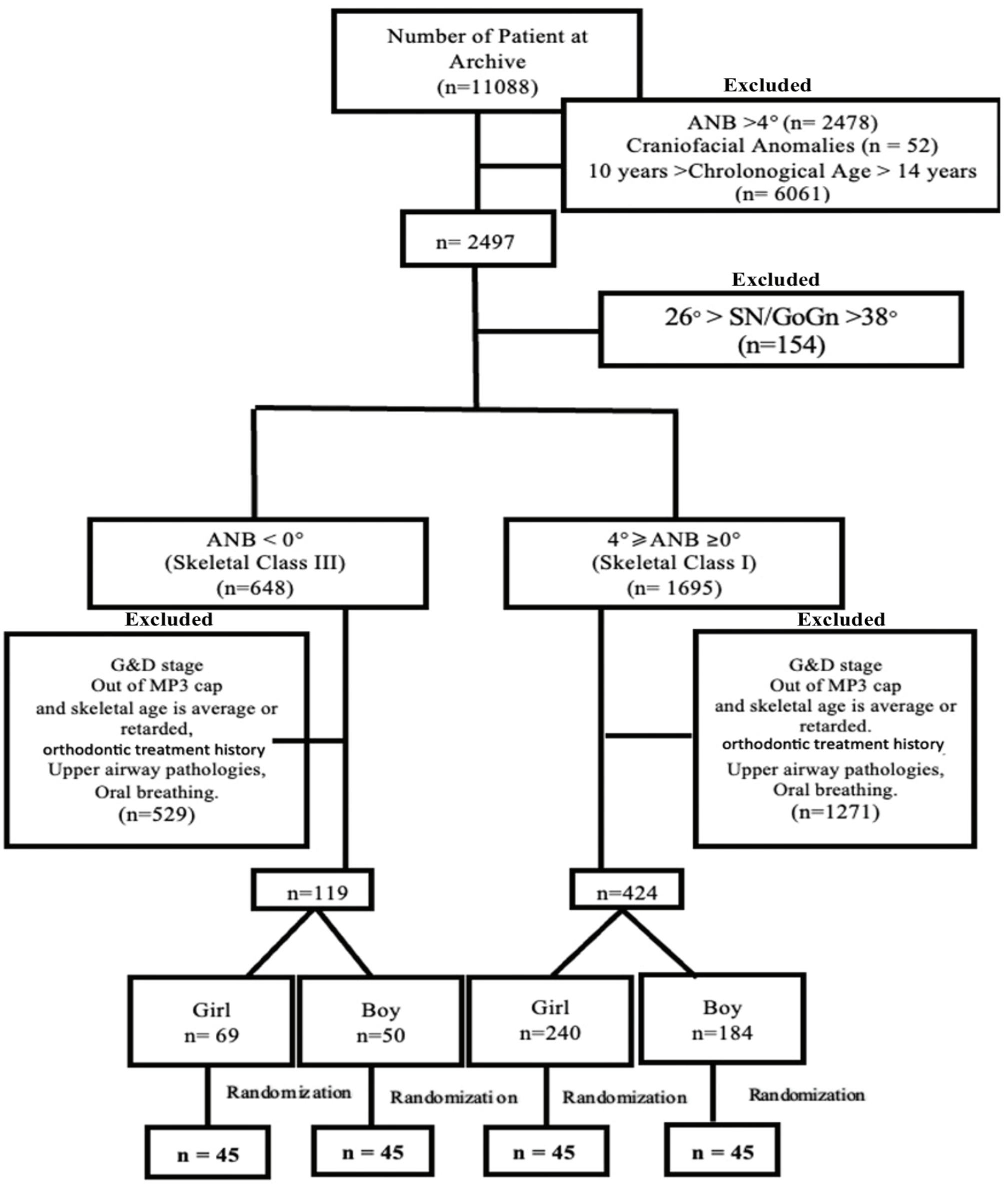

Figure 1. Flow chart for patient selection criteria

width (SPS), along with a more anterior and lower hyoid bone position compared to Class I girls (p<0.05) (Tables 2, 3).

Comparisons Between Gender

Mandibular effective length (Co-Gn) was found to be greater in Class I boys than Class I girls (p<0.01). N-Me, ANS-Me, and H-SN dimensions were found to be greater whereas SNB angle is smaller in Class I boys than in Class I girls (p<0.001). The S-PNS in Class I boys was found to be greater than in Class I girls (p<0.01). Girls with Class I malocclusion have a more extensive head position than boys due to SN/CVT angle (p<0.05).

The skeletal measurements of boys and girls exhibiting Class III malocclusion were comparable. In Class III girls, OA (p<0.05), RG (p<0.01), SPS (p<0.05), lower airway width (IPS) (p<0.05), and airway width at epiglottis level (eb-Peb) (p<0.05) were found to be greater than those in Class III boys. The hyoid position relative to the mandible (H-MP) was significantly lower in Class III girls compared to Class III boys (p<0.01). Class III girls exhibit a more pronounced head position compared to Class III boys (p<0.001) (Tables 2, 3).

Regression Analysis

The multiple linear regression analysis utilizing the "forward selection" method indicated that in Class III boys, cephalometric measurements and NA are significantly explained by SNA, while RP area is significantly explained by N-Me (p<0.05) (Tables 4, 5). The regression model indicates that the RP area is explained by the N-ANS and Co-A variables, while NA is explained by the Co-Gn length in Class III girls (p<0.05) (Tables 4, 5).

DISCUSSION

Orthodontic treatment may potentially affect the upper airway.[15] Narrowing of the upper respiratory tract can lead to snoring and obstructive sleep apnea (OSA), adversely impacting sleep quality.[15] Recent investigations indicate that patients with OSA display dentofacial morphological characteristics linked to a constricted upper airway, including a retrusive mandible, a vertical mandibular plane, a dorsally positioned tongue, and an extended soft palate.[17] The literature discusses the impacts of various orthodontic, orthopedic, functional, and orthognathic surgical interventions on the upper airway.[4-7] Additionally, several studies evaluated the upper airway according to various types of malocclusions.[2,3,7,11,18] However, these studies often had a wide distribution of ages among the malocclusion groups, based on chronological age, or evaluated both genders together. Buyukcavus et al.[2] did not consider the vertical dimension in their classification of Class III patients, grouping them solely based on the ANB, SNA, SNB values as maxillary retrognathism, mandibular prognathism, or a combination of them. In our study, we classified the patients based on the Co-A and Co-Gn values, the ideal SN/GoGn angle range was chosen considering the vertical dimension known to affect the airway. This study represents the first evaluation of airways in Class III patients during the MP3cap growth period. This study

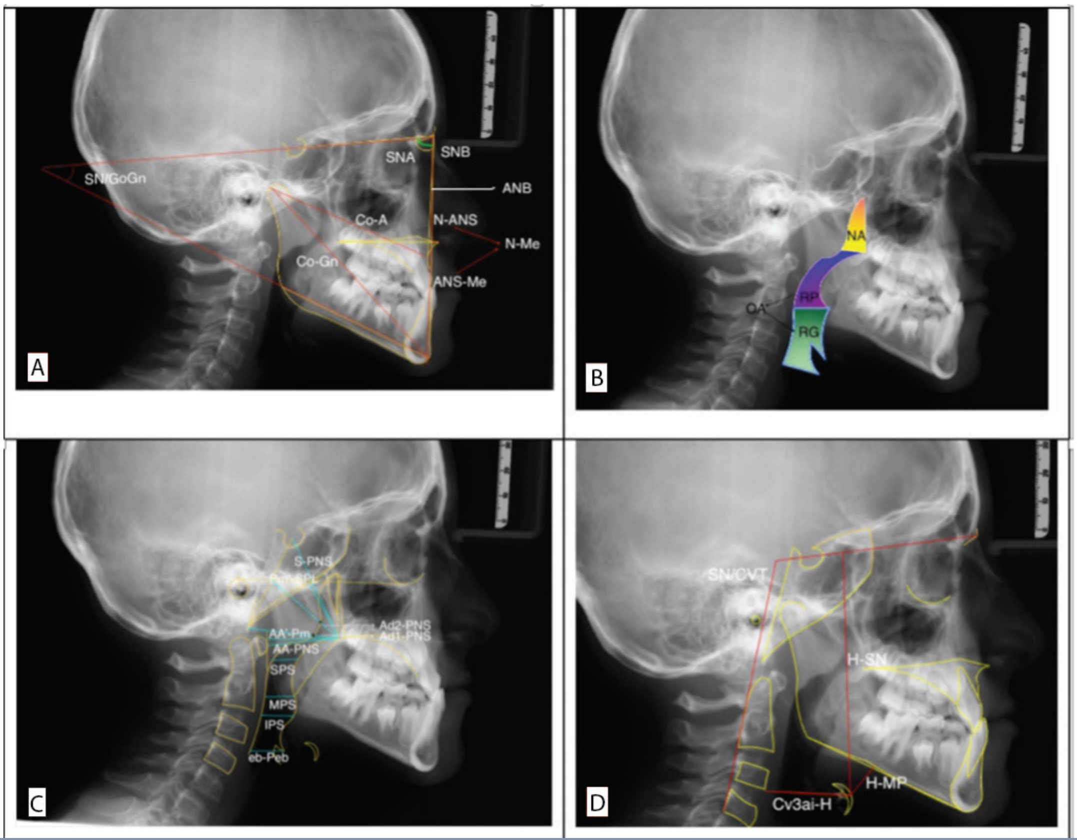

Figure 2. Skeletal landmarks and measurements used in study

establishes the normative values of airway dimensions in patients with Class I dentofacial structure during the MP3cap growth period for both genders.

Bench et al.[19] reported that the level of the hyoid bone descends with chronological age. Developmental changes are observed in both pharyngeal airway depth and hyoid position with chronological age.[19,20] The sagittal nasopharyngeal airway is narrowest at five years of age, increases until ten slightly decreases between 10-11 years of age, and increases again after 11 years of age.[20] However, there is no study in the literature that has considered skeletal ages during airway evaluation and several studies have reported a significant but low correlation between chronological ages and skeletal ages in girls.[21,22] Utilizing comparable skeletal ages and growth periods may reduce the influence of age, yielding more precise data in evaluating airway dimensions and facilitating a deeper comprehension of airway development and changes during growth. Boys in both malocclusion groups demonstrated greater skeletal and chronological ages compared to girls, with a statistically significant difference observed. This disparity is due to the earlier onset of the growth spurt (MP3cap) in girls compared to boys during the growth and development phase.

The gold standard method for diagnosing OSA is polysomnography (PSG).[23] However, cone-beam computed tomography (CBCT) has gained popularity as a convenient and less time-consuming diagnostic tool, especially due to its relatively lower cost as compared to PSG.[24] While lateral cephalograms created using CBCT images are considered a practical and convenient method to assess the airway, there may be differences observed on the right and left sides.[25] The lateral cephalogram is a simple, low-cost, and easily renewable 2-dimensional image that is more suitable for retrospective studies. Pracharktam et al.[26] evaluated the upper airway passage in two positions, sitting upright and lying down, and reported similar airway measurements between the two positions using 2D cephalograms. In our study, lateral cephalograms were taken while the patients were in their natural upright position.

Table 1. Skeletal landmarks and measurements utilized in the study

Nazopharyngeal area (NA; mm²)	The posterior wall has a convex contour from the upper point of the pterygomaxillary fissure to point ad2, where the tangent to the sphenoid bone curvature intersects the posterior pharyngeal wall. It continues with a concave contour to point ad1, where the Ba-PNS line intersects the posterior pharyngeal wall. This area is bounded below by the palatal plane and in front by the PTV plane, which is perpendicular to the FH plane from point Pm.
Oropharyngeal area (OA; mm²)	The area bounded above by the palatal plane, below by the base of the epiglottis, posteriorly and anteriorly pharyngeal wall.
Retropalatal area (RP; mm²)	The area of the region that extends from the level of the hard palate to the caudal limit of the soft palate.
Retroglossal area (RG; mm²)	The area extends from the caudal border of the soft palate to the base of the epiglottis.
S-PNS (mm)	The distance between point S and PNS.
ad1-PNS (mm)	The distance between ad1 (the point where the Ba-PNS line intersects the posterior pharyngeal wall) and PNS.
ad2-PNS (mm)	The distance between ad2 (the point where the line extending from the midpoint of the Ba-S line intersects the posterior pharyngeal wall) and PNS.
AA'-Pm' (mm)	The distance between the points where the perpendiculars from the most anterior projecting point of the atlas and the pterygomaxillary point intersect the palatal planes.
Pm'-SPL (mm)	The distance from Pm to the vertical projection point of the line perpendicular to the FH plane on the pharyngeal wall, to the tangent line of the sphenoid bone's lower boundary, starting from Basion.
AA-PNS (mm)	The distance between the point where the tangent drawn perpendicularly from the most anterior point of the atlas intersects the palatal plane and PNS.
MPS (mm)	The distance between the lowest point of the soft palate (P) and the point where the line drawn parallel to the FH plane from this point intersects the pharyngeal wall (Pp).
SPS (mm)	The distance between the points where the anterior and posterior pharyngeal walls intersect lines drawn parallel to the FH plane from the midpoint of the soft palate.
IPS (mm)	The distance between the points where a line drawn parallel to the FH plane from the most anterior and inferior edge of the 2nd cervical vertebra (CV2ai) intersects the anterior and posterior pharyngeal walls.
eb-Peb (mm)	The distance between the point where the line extending parallel to the FH plane from the vallecula epiglottis intersects the posterior pharyngeal wall and the vallecula epiglottis.
H-MP (mm)	The perpendicular distance from the most anterior point of the hyoid bone to the mandibular plane.
H-SN (mm)	The perpendicular distance from the most anterior point of the hyoid bone to the SN plane.
Cv3ai-H (mm)	The distance between the most anterior and inferior point of the 3rd cervical vertebra and the most anterior point of the hyoid bone.
SN/CVT (°)	The angle between the SN and CVT planes.

FH: Frankfort horizontal

Table 2. Comparison of the skeletal measurements of boys and girls with Class I and III malocclusions

Measurements		Class I			Class III			Class I vs Class III	
		Boys	Girls	p-value	Boys	Girls	p-value	Boys p-value	Girls p-value
Maxillary	SNA (°)	79.4±2.9	79.7±3.3	0.622	78.2±4.4	77.7±3.3	0.591	0.121	0.005**
	Co-A (mm)	79.5±4.0	78.0±4.5	0.097	76.2±4.6	74.8±3.5	0.102	**<0.001*****	**<0.001*****
Mandibular	SNB (°)	77.0 (68-85)	77.0 (70-85)	**<0.001*****	81.0 (71-90)	80.0 (74-88)	0.694	**<0.001*****	**<0.001*****
	Co-Gn (mm)	102.6±5.5	99.4±5.9	**0.010****	104.2±5.5	102.0±5.4	0.062	0.155	**0.028***
Maxillo-mandibular	ANB (°)	2.3±1.1	2.6±1.1	0.292	-2.8±2.0	-2.7±1.3	0.691	**<0.001*****	**<0.001*****
Vertical	SN/GoGn (°)	34.4±2.5	33.6±2.5	0.159	33.3±3.0	34.2±2.7	0.131	0.072	0.274
	N-Me (mm)	109.3±5.8	104.2±5.9	**<0.001*****	107.1±9.9	106.7±6.3	0.820	0.196	0.060
	N-ANS (mm)	48.8±3.3	47.6±3.2	0.095	49.2±2.8	48.3±2.8	0.154	0.537	0.262
	ANS-Me (mm)	61.0 (50-71)	57.0 (45-65)	**<0.001*****	58.0 (50-71)	58.0 (50-71)	0.695	0.107	0.115

Data were presented as mean±standard deviation or median (min.-max.)
P<0.05 as statistically significant
*p=0.05; **p=0.01; ***p=0.001

Table 3. Comparison of the pharyngeal airway measurements of boys and girls with Class I and III malocclusions

Measurements	Class I			Class III			Class I vs Class III	
	Boys	Girls	p-value	Boys	Girls	p-value	Boys p-value	Girls p-value
NA (mm^2)	270.9±79.6	261.3±80.1	0.569	268.0±68.9	253.8±72.5	0.341	0.857	0.643
OA (mm^2)	491.4±126.2	461.5±108.2	0.230	483.9±125.6	551.1±126.0	0.013	0.777	**<0.001*****
RP (mm^2)	270.7±52.7	248.6±62.2	0.074	276.8±70.6	270.7±60.1	0.659	0.643	0.090
RG (mm^2)	224.0 (31-571)	212.9±88.3	0.831	217.0 (8.0-382)	280.4±100.0	0.002	0.693	**0.001*****
S-PNS (mm)	42.2±2.8	40.4±2.1	**0.001*****	42.1±2.7	41.7±3.0	0.482	0.908	**0.015***
ad1-PNS (mm)	19.0 (11-25)	19.0 (7-28)	0.543	19.0 (12-28)	19.0 (7-25)	0.538	0.789	0.234
ad2-PNS (mm)	15.0 (7.0-24)	15.0 (5-23)	0.842	15.0 (10-23)	14.0 (7-38)	0.068	0.202	0.478
AA'-Pm' (mm)	27.8±3.1	27.4±3.3	0.575	26.1±3.4	26.8±3.5	0.343	0.016*	0.384
Pm'-SPL (mm)	29.0±3.7	27.7±3.3	0.096	28.0±3.3	27.8±3.2	0.744	0.200	0.922
AA-PNS (mm)	28.8±3.0	28.6±3.0	0.699	27.2±3.0	27.8±3.3	0.346	0.011*	0.256
MPS (mm)	10.0±2.9	9.2±2.7	0.181	9.3±2.4	10.0±2.0	0.190	0.254	0.131
SPS (mm)	10.6±2.3	10.8±2.6	0.735	10.6±2.3	12.0±2.8	**0.010****	0.964	**0.032***
IPS (mm)	9.0 (4.0-14)	9.7±3.2	0.526	9.0 (6-18)	10.7±2.9	**0.014***	0.769	0.135
eb- Peb (mm)	13.7±2.3	14.4±3.1	0.178	13.2±2.8	14.6±3.5	**0.046***	0.394	0.873
H-MP (mm)	11.0±4.0	12.0 (5-24)	0.474	11.8±3.9	15.0 (6-31)	**0.004****	0.342	**0.007****
H-SN (mm)	94.4±7.0	88.5±7.5	**<0.001*****	95.7±6.8	93.6±6.2	0.123	0.384	**0.001*****
Cv3ai-H (mm)	24.3±2.8	24.5±2.8	0.704	24.6±3.0	25.8±2.8	0.060	0.559	**0.030**
SN/CVT (°)	103.1±8.3	108.0±10.3	**0.015***	101.8±9.2	108.9±8.7	**<0.001*****	0.465	0.650

Data were presented as mean±standard deviation or median (min.-max.)
P<0.05 as statistically significant
*p=0.05; **p=0.01; ***p=0.001

Table 4. Results of the multiple linear regression analysis of cephalometric measurements with NA in Class III girls and boys

Gender	Independent variables	B	SE	β	p-value	95% CI (Upper-Lower)	Regression
Boys	SNA (°)	5.839	2.208	0.374	**0.011***	(1.388;10.291)	F=6.997 p=0.011 adj. R^2=0.120
Girls	Co-Gn (mm)	4.110	1.959	0.305	**0.042***	(0.159;8.061)	F=4.401 p=0.042 adj. R^2=0.072

adj. R^2: Adjusted explained variance
*P<0.05 as statistically significant
B, non-standardized coefficient; β, standardized coefficient; SE, standard error; CI, confidence interval; NA, nasopharyngeal area

Table 5. Results of the multiple linear regression analysis of cephalometric measurements with RP in Class III girls and boys

Gender	Independent variables	B	SE	β	p-value	95% CI (Upper-Lower)	Regression
Boys	N-Me (mm)	2.692	1.021	0.377	**0.012***	(0.631;4.752)	F=4.039 p=0.025 adj. R^2=0.121
	SNB (°)	3.215	2.242	0.205	0.159	(-1.311;7.740)	
Girls	N-ANS (mm)	7.820	2.959	0.361	**0.012***	(1.849;13.792)	F=5.752 p=0.006 adj. R^2=0.178
	Co-A (mm)	4.795	2.342	0.280	**0.047***	(-0.067;9.522)	

adj. R^2: Adjusted explained variance
*P<0.05 as statistically significant
B, non-standardized coefficient; β, standardized coefficient; SE, standard error; CI, confidence interval

Bozzini et al.[27] employed a 40-second protocol for CBCT scanning, sufficient for patients to hold their breath and stabilize their head position. Hong et al.[28] employed a 15-second time protocol for CBCT scanning. The duration required to obtain lateral cephalometric radiographs in our study was 14.9 seconds. The short duration facilitates breath-holding in patients, resulting in more dependable radiographs for airway evaluation.

Ucar et al.[29] observed that low-angle patients exhibited a greater nasopharyngeal airway area and upper airway dimensions than high-angle patients. Alhammadi et al.[30] reported that vertical positioning of the mandible enhances airway volume while accommodating collapse resulting from the posterior position of the mandible. Only patients exhibiting optimal vertical growth patterns were included in this study to minimize variation. Since the literature shows differing opinions on the relationship between gender and airway dimensions,[10,14,31] the airway was evaluated separately for each gender in this study.

Jena et al.[9] reported that skeletal parameters, particularly mandibular prognathism, influence airway dimensions. This study included only Class III patients from the maxilla or maxillomandibular regions, excluding those from the mandible. The present study indicates that Class III boys exhibited significantly lower measurements of pharyngeal width in the anteroposterior direction at the adenoid level (AA-PNS, AA'-Pm') compared to Class I boys. Class III girls exhibited a significantly larger OA and RG area in comparison to Class I girls. Furthermore, SPS and IPS measurements exhibited greater values in Class III girls. The observed results may be attributed to the inferior and anterior positioning of the hyoid bone, along with an extended head posture in Class III girls. Consistent with our findings; Iwasaki et al.[10] reported that Class III patients exhibited a wider oropharyngeal airway than Class I patients at 8 years of chronological age using CBCT images. Trenouth and Timms reported a positive correlation between oropharyngeal airway and mandibular length in children aged 10 to 13.[32] However, Takemoto et al.[13] found that the lower pharyngeal airway size was larger in Class III girls originating from the mandible compared to those in Class I; however, no significant differences were noted in the sizes of the upper airway. The study found that an anterior mandibular position in girls aged 7-8 years correlates with an increased width of the lower pharyngeal airway.

Takemoto et al.[13] observed no significant differences in upper airway dimensions between Class III and Class I girls at the age of 8. Zhong et al.[33] classified Class I and Class III Chinese children according to mandibular plane angle and ANB angle, revealing no significant differences in upper pharyngeal space measurements. Chan et al.[34] similarly found no significant differences in the nasopharyngeal region across various malocclusions. The authors found that NA was comparable in both Class III and Class I groups across genders. The patients in our study had an average age of approximately 12 years, and the growth and development of the airway were found to be more stable, as reported by Taylor et al.[35].

Ceylan and Oktay[11] reported a negative impact of an elevated ANB angle on the dimensions of the NA in their study, which evaluated both genders collectively and compared Class I, II, and III malocclusions. All subjects in the study were aged between 13 and 15 years. No significant differences in NA were observed between Class I and Class III malocclusion groups across both genders. The regression analysis indicated that NA is explicable by SNA in Class III boys and Co-Gn in Class III girls. No significant difference was observed in the SNA angle between Class III and Class I boys. The anticipated increase in NA for Class III girls, linked to the rise in mandibular effective length, was not observed. This absence of difference may be explained by the malocclusion stemming from maxilla-mandibular discrepancy and a reduced SNA angle. The authors found that an increased ANB angle correlated with a decrease in OA and noted a higher positioning of the hyoid bone in Class III children compared to Class I children. In contrast to that study, our research indicates that the hyoid bone is positioned lower, and the OA was larger exclusively in Class III girls.

A significant regression model was identified in Class III girls, linking RP area, upper anterior facial height, and upper maxillary effective size. Bozzini et al.[27] reported a moderate positive correlation between nasal area and facial height, as well as between the RP area and upper anterior facial height in Class III girls approximately 26 years of age.

Gökçe et al.[14] conducted a comparison of pharyngeal measurements between male and female adults with Class I malocclusion, revealing statistically significant greater sagittal pharyngeal dimensions in males, with the exception of craniocervical angles related to head posture. Our study revealed that only S-PNS was significantly greater in Class I boys, while other pharyngeal measurements were comparable between genders within the Class I malocclusion group. This discrepancy may be attributed to the age differences between our study and that of Gökçe et al.[14].

Hellsing et al.[36] found correlation between head position and cervical lordosis, on lateral cephalograms; increase in the size of the pharyngeal airway. Huggare et al.[37] found that head extension positively influenced nasorespiratory function. The present study noted an increase in airway dimensions in Class III females, characterized by an extended head (an increase of 200 in the SN/OPT angle) and a lowered hyoid bone position. In contrast to our study, Alves et al.[25] evaluated adult patients and found that RP and RG volumes were significantly larger in Class III males compared to Class III females.

The McNamara analysis[12] indicates that in the Ann Arbor adult samples, the average upper airway measurement is 17.4 mm, with a tendency for this measurement to increase with age. The mean lower airway measurements range from 10 to 12 mm, with no significant changes observed with age. In the present study, we found that the median [minimum, maximum (min., max.)] upper airway measurements (ad1-PNS) for Class I and Class III boys were 19 (11, 25) mm and 19 (7, 28) mm, respectively. The median lower airway measurements (IPS) were 9 (4, 14) mm and 9 (6, 18) mm, respectively. The median (min., max.) upper airway measurements (ad1-PNS) for Class I and Class III girls were 19.0 (7-28) mm and 19.0 (7-25) mm, respectively. The median lower airway measurements (IPS) were 9.7±3.2 mm and 10.7±2.9 mm, respectively. The findings underscore the importance of gender differences in airway measurements.

Our results indicate that the airway must be thoroughly assessed in orthodontic diagnosis and treatment planning, considering age-related factors for each gender. In particular, the application of treatments that narrow the airway and induce clockwise rotation of the mandible may be approached with reduced clinical concern in females, given that this area is wider compared to males of the same age. Furthermore, implementing multidisciplinary treatments in conjunction with ENT specialists would be advantageous.

Strengths and Limitations

All patients' radiographs were obtained using the same cephalometric radiography device, in a consistent environment, and with subjects positioned in a natural head posture. Furthermore, patients were chosen within a defined age range (10-14 years) and at the same growth and development stage (MP3cap) to minimize age-related variations. Additionally, to control for gender effects, measurements were assessed independently for each gender and subsequently compared across genders.

Multiple measurements were conducted to characterize the airway, thus eliminating dependence on a singular parameter. The study participants demonstrated optimal vertical growth direction.

A limitation of this study may be the absence of assessment for body mass index or obesity scores, attributable to its retrospective design. Additional limitations include the absence of longitudinal follow-up and the reliance on two-dimensional evaluation for assessing the pharyngeal airway. Future research should employ longitudinal designs to monitor alterations in airway dimensions over time. Additionally, focusing on Class III patients with mandibular prognathism and integrating comprehensive clinical evaluations of breathing by ear, nose, and throat specialists would be advantageous.

CONCLUSION

There are no differences in the nasopharyngeal area dimensions when comparing different malocclusion groups or genders. In Class III girls, the oropharyngeal, RG, and superior pharyngeal space were larger than Class III boys, and larger than Class I girls. The inferior pharyngeal space was larger in Class III girls than Class III boys. Girls with both Class I and Class III malocclusions exhibited a more extensive head posture compared to boys.

Ethics

Ethics Committee Approval: The study protocol received approval from the Measurement and Evaluation Ethics Sub-Working Group of the Gazi University (approval no.: 2020-465, date: 08.09.2020).

Informed Consent: Informed consent forms were obtained from each patient.

Footnotes

Author Contributions: Surgical and Medical Practices - M.K., E.K.; Concept - M.K., E.K.; Design - E.K.; Data Collection and/or Processing - M.K.; Analysis and/or Interpretation - B.Ç.; Literature Search - M.K., B.Ç., E.K.; Writing - M.K., B.Ç., E.K.

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REFERENCES

1. Florez BM, Tagawa DT, Inoue DP, Yamashita HK, de Arruda Aidar LA, Dominguez GC. Associations between skeletal discrepancies, breathing pattern, and upper airway obstruction in Class III malocclusions. *Int J Pediatr Otorhinolaryngol.* 2023;166: 111471. [CrossRef]
2. Buyukcavus MH, Kocakara G. Comparing Pharyngeal Airway Dimensions and Hyoid Bone Position in the Subgroups of Skeletal Class III Malocclusions: A Cephalometric Study. *J Adv Oral Res.* 2021;(1):86-94. [CrossRef]
3. Kostiuchenko-Faifor OS, Gunas IV, Glushak AA, Babych LV, Skoruk RV. Peculiarities of correlations of upper respiratory tract cephalometric parameters in Ukrainian young men and young women regardless of face type. *Reports of Morphology.* 2023;29(1):15-23. [CrossRef]
4. Kaygisiz E, Tuncer BB, Yüksel S, Tuncer C, Yildiz C. Effects of maxillary protraction and fixed appliance therapy on the pharyngeal airway. *Angle Orthod.* 2009;79(4):660-667. [CrossRef]
5. Ming Y, Hu Y, Li Y, Yu J, He H, Zheng L. Effects of maxillary protraction appliances on airway dimensions in growing class III maxillary retrognathic patients: A systematic review and meta-analysis. *Int J Pediatr Otorhinolaryngol.* 2018;105:138-145. [CrossRef]
6. Efendiyeva R, Aydemir H, Karasu H, Toygar-Memikoğlu U. Pharyngeal airway space, hyoid bone position, and head posture after bimaxillary orthognathic surgery in Class III patients: long-term evaluation. *Angle Orthod.* 2014;84(5):773-781. [CrossRef]
7. Kaygisiz E, Ocakoglu G, Kurnaz M, Yüksel S, Tortop T. Geometric morphometric analysis of the pharyngeal airway during treatment of Class III malocclusion. *Am J Orthod Dentofacial Orthop.* 2022;162(3):374-385. [CrossRef]
8. Havakeshian G, Koretsi V, Eliades T, Papageorgiou SN. Effect of Orthopedic Treatment for Class III Malocclusion on Upper Airways: A Systematic Review and Meta-Analysis. *J Clin Med*. 2020;9(9):3015. [CrossRef]
9. Jena AK, Singh SP, Utreja AK. Sagittal mandibular development effects on the dimensions of the awake pharyngeal airway passage. *Angle Orthod*. 2010;80(6):1061-1067. [CrossRef]
10. Iwasaki T, Hayasaki H, Takemoto Y, Kanomi R, Yamasaki Y. Oropharyngeal airway in children with Class III malocclusion evaluated by cone-beam computed tomography. *Am J Orthod Dentofacial Orthop.* 2009;136(3):318. [CrossRef]
11. Ceylan I, Oktay H. A study on the pharyngeal size in different skeletal patterns. *Am J Orthod Dentofacial Orthop.* 1995;108(1):69-75. [CrossRef]
12. McNamara JA Jr. A method of cephalometric evaluation. *Am J Orthod*. 1984;86(6):449-469. [CrossRef]
13. Takemoto Y, Saitoh I, Iwasaki T, et al. Pharyngeal airway in children with prognathism and normal occlusion. *Angle Orthod*. 2011;81(1):75-80. [CrossRef]
14. Gökçe SM, Görgülü S, Gökçe HS, Bengi AO, Sağdıç D. Sağlıklı bireylerde farengeal hava yolu, dil boyutlarının ve hyoid pozisyonun belirlenmesi. *Gulhane Medical Journal.* 2013;55(2). [CrossRef]
15. Bucci R, Rongo R, Zunino B, et al. Effect of orthopedic and functional orthodontic treatment in children with obstructive sleep apnea: A systematic review and meta-analysis. *Sleep Med Rev.* 2023;67:101730. [CrossRef]
16. Aboudara CA, Hatcher D, Nielsen IL, Miller A. A three-dimensional evaluation of the upper airway in adolescents. *Orthod Craniofac Res.* 2003;6(Suppl 1):173-175. [CrossRef]
17. Shigeta Y, Ogawa T, Tomoko I, Clark GT, Enciso R. Soft palate length and upper airway relationship in OSA and non-OSA subjects. *Tex Dent J.* 2013;130(3):203-211. [CrossRef]
18. Mucedero M, Baccetti T, Franchi L, Cozza P. Effects of maxillary protraction with or without expansion on the sagittal pharyngeal dimensions in Class III subjects. *Am J Orthod Dentofacial Orthop*. 2009;135(6):777-781. [CrossRef]
19. Bench RW. Growth of the cervical vertebrae as related to tongue, face, and denture behavior. *Am J Orthod*. 1963;49(3):183-214. [CrossRef]
20. Linder-Aronson S, Leighton BC. A longitudinal study of the development of the posterior nasopharyngeal wall between 3 and 16 years of age. *Eur J Orthod*. 1983;5(1):47-58. [CrossRef]
21. Dahlberg PS, Mosdøl A, Ding Y, et al. A systematic review of the agreement between chronological age and skeletal age based on the Greulich and Pyle atlas. *Eur Radiol.* 2019;29(6):2936-2948. [CrossRef]
22. Bala M, Pathak A, Jain RL. Assessment of skeletal age using MP3 and hand-wrist radiographs and its correlation with dental and chronological ages in children. *J Indian Soc Pedod Prev Dent*. 2010;28(2):95-99. [CrossRef]
23. Michaelson PG, Allan P, Chaney J, Mair EA. Validations of a portable home sleep study with twelve-lead polysomnography: comparisons and insights into a variable gold standard. *Ann Otol Rhinol Laryngol*. 2006;115(11):802-809. [CrossRef]
24. Nath M, Ahmed J, Ongole R, Denny C, Shenoy N. CBCT analysis of pharyngeal airway volume and comparison of airway volume among patients with skeletal Class I, Class II, and Class III malocclusion: A retrospective study. *Cranio*. 2021;39(5):379-390. [CrossRef]
25. Alves PV, Zhao L, O'Gara M, Patel PK, Bolognese AM. Three-dimensional cephalometric study of upper airway space in skeletal class II and III healthy patients. *J Craniofac Surg.* 2008;19(6):1497-1507. [CrossRef]
26. Pracharktam N, Nelson S, Hans MG, et al. Cephalometric assessment in obstructive sleep apnea. *Am J Orthod Dentofacial Orthop.* 1996;109(4):410-419. [CrossRef]
27. Bozzini MFR, Valladares-Neto J, Paiva JB, Rino-Neto J. Sex differences in pharyngeal airway morphology in adults with skeletal Class III malocclusion. *Cranio*. 2018;36(2):98-105. [CrossRef]
28. Hong JS, Oh KM, Kim BR, Kim YJ, Park YH. Three-dimensional analysis of pharyngeal airway volume in adults with anterior position of the mandible. *Am J Orthod Dentofacial Orthop.* 2011;140(4):e161-e169. [CrossRef]
29. Ucar FI, Uysal T. Orofacial airway dimensions in subjects with Class I malocclusion and different growth patterns. *Angle Orthod.* 2011;81(3):460-468. [CrossRef]
30. Alhammadi MS, Almashraqi AA, Halboub E, et al. Pharyngeal airway spaces in different skeletal malocclusions: a CBCT 3D assessment. *Cranio*. 2021;39(2):97-106. [CrossRef]

31. Brown IG, Zamel N, Hoffstein V. Pharyngeal cross-sectional area in normal men and women. *J Appl Physiol (1985). 1986*;61(3):890-895. [CrossRef]
32. Trenouth MJ, Timms DJ. Relationship of the functional oropharynx to craniofacial morphology. *Angle Orthod.* 1999;69(5):419-423. [CrossRef]
33. Zhong Z, Tang Z, Gao X, Zeng XL. A comparison study of upper airway among different skeletal craniofacial patterns in nonsnoring Chinese children. *Angle Orthod.* 2010;80(2):267-274. [CrossRef]
34. Chan L, Kaczynski R, Kang HK. A cross-sectional retrospective study of normal changes in the pharyngeal airway volume in white children with 3 different skeletal patterns from age 9 to 15 years: Part 1. *Am J Orthod Dentofacial Orthop.* 2020;158(5):710-721. [CrossRef]
35. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. *Angle Orthod.* 1996;66(5):393-400. [CrossRef]
36. Hellsing E. Changes in the pharyngeal airway in relation to extension of the head. *Eur J Orthod*. 1989;11(4):359-365. [CrossRef]
37. Huggare JA, Laine-Alava MT. Nasorespiratory function and head posture. *Am J Orthod Dentofacial Orthop.* 1997;112(5):507-511. [CrossRef]