Original Article

Correlation between Upper Airway Volume and Morphology with Skeletal Malocclusions in Adults with Normal Sagittal Position of the Mandible Using Cone Beam Computed Tomography

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Abstract

Objectives: To investigate the effects of Class I, II, and III malocclusions on upper airway (UA) volume and shape in adult normal mandibular position subjects using a Cone Beam Computed Tomography (CBCT).

Methods: This cross-sectional study recruited 60 adults (20 per group) with Class II and III skeletal malocclusions (SM) and a normal sagittal mandibular position (Class I) between November 2024 and April 2025 at the Oral and Maxillofacial clinics, Dental Clinic, College of Dentistry, University of Sulaimani, Sulaymaniyah, Kurdistan Region, Iraq. The 3D images of the upper airway were obtained via CBCT, and the volumes of the nasopharynx, oropharynx, and hypopharynx were measured and statistically compared.

Results: Among individuals, 35 were women, and 25 were men, yielding a gender ratio of 1.4:1. Ages ranged from 19 to 38 years, with a mean of 28.82 ± 5.87 years. The nasopharyngeal volumes for Class III patients were significantly larger (12.97 ± 2.04 cm^3) compared to Class I (8.96 ± 1.55 cm^3) and Class II (7.89 ± 0.96 cm^3) ($p < 0.001$). Significant differences were reported between the oropharynx and hypopharynx, with the most essential volumes in Class III patients, who had a higher prevalence of elongated airway morphology (35%). In contrast, Class II patients had a higher proportion of collapsed airway morphology (15%).

Conclusions: SM in Class III are associated with larger nasopharyngeal, oropharyngeal, and hypopharyngeal volumes than in other classes, reflecting anatomical associations rather than causation.

Keywords: *Airway morphology, Cone Beam Computed Tomography, Skeletal malocclusion, Upper airway.*

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Introduction

A relationship has been established between craniofacial morphology and the UA, with significant implications for respiration. Alterations in UA volume are known to be associated with different forms of SM studied experimentally, such as Classes II and III, which may be linked to their functions regarding breathing performance and health[1]. Dental bite classifications, including Class I, II, and III malocclusions, are based on the relationship between the upper and lower first molars. A Class I bite has a normal molar relationship, a Class II bite shows the lower jaw is behind the upper jaw, and a Class III bite shows the lower jaw is in front of the upper jaw[2].

Cone Beam Computed Tomography (CBCT) is a recent imaging modality for the accurate delineation of skeletal configurations and airway dimensions. Its three-dimensional (3D) volumetric measurements provide information on airway morphology and its structural correlation to skeletal malocclusions (SM)[3,4]. The sagittal area of the mandible is commonly a baseline reference for evaluating airway size differences in adults[5]. Differences in airway volume may be correlated to the distinct outlines of vertical growth, palatal inclinations, and maxillary widths. Considering these associations is important for orthodontists, chiefly in patients with a history of orthognathic surgery and/or management of an occlusal discrepancy, to recover craniofacial growth and development, preferably serving to normalize airway-linked physiological function[6]. Volumetric CBCT studies demonstrate differences in upper-airway dimensions across skeletal patterns, even when the mandibular sagittal position is normal. To limit confounding from mandibular prognathism/retrognathism, SNB (sella [S], nasion [N], and point B is a cephalometric angle measured on a lateral skull X-ray to determine the position of the mandible relative to the anterior cranial base and is constrained to a normative range (78°–82°) between-class comparisons[7].

Studies suggest that individuals with either increased vertical proportions of the face or retrognathic maxillae have lower pharyngeal airway volumes and may be more prone to airway obstruction. Volumetric assessment of the airway on CBCT provides a standardized method for characterizing airway constrictions and can serve as a tool for early intervention among persons at risk[8]. Thus, efforts were made to restrict the latter by using an adult sample with normal mandibular position and to exclude confounding factors by separately assessing the effects of skeletal and dental morphology on airway dimensions. This offers a better appreciation of the craniofacial aspects that impact respiration[9]. An accurate assessment of the airway is increasingly appreciated in both orthodontic and oral/maxillofacial surgery treatment planning. Traditional cephalometry cannot accurately represent the 3D morphology of the UA; therefore, CBCT is required for a more accurate assessment[10]. This study aimed to determine the effects of SM on airway dimensions and morphology in patients with a normal mandibular position, Class II, and Class II SM without temporomandibular disorder (TMD), using CBCT, with a specific focus on molar and canine relationships.

Patients and methods

Research design and setting

This cross-sectional study was conducted from December 2024 to April 2025. Ethical approval was obtained from the College of Dentistry, University of Sulaimani, with approval No: 24-257 on December 16, 2024. Sixty adult participants with skeletal Class I, II, and III malocclusions (n=20 each) were recruited from the Oral and Maxillofacial Clinic, College of Dentistry, University of Sulaimani, Sulaymaniyah, Iraq. Imaging was done when participants were placed in a standardized sagittal mandibular position. With emphasis on the nasopharynx, oropharynx, and hypopharynx, the interrelation between the SM and the UA volume was also assessed. Examining the effects of malocclusion on UA size and its relationship to molar and canine relationships was the primary goal.

Inclusion criteria

Participants aged ≥18 years who were diagnosed with SM Class II or III or confirmed normal sagittal mandibular position through clinical and radiographic assessments. Patients included in this study were those who attended the clinic for full-skull radiographic examination based on a clear clinical indication. Before inclusion, each patient underwent a clinical assessment for TMD, including history taking for jaw pain, joint sounds, limited or deviated mouth opening, chewing pain, and temporal headache, followed by a standardized examination of the temporomandibular joint and masticatory muscles. Patients without clinical signs or symptoms of TMD were included.

Exclusion criteria

Individuals with craniofacial abnormalities, a history of thumb-sucking beyond age 5 years old, chronic tonsillitis, significant airway obstruction, facial reconstructive surgery or fillers, smoking history, cancer (particularly head and neck cancers), obesity (body mass index of ≥30), sleep apnea, and TMD (to ensure the focus on the effects of malocclusion on airway volume).

CBCT acquisition and processing

All CBCT scans were performed using a Carestream 9600 machine with a field of view (16×17 cm) and exposure settings (120 kV, 5.0 mA, 40 seconds). Patients were positioned in a standard head posture, with their teeth in maximum intercuspation, and instructed to breathe normally without swallowing during the scan to ensure consistency across scans. The isotropic voxel size was 0.30 cm, and volumes were reconstructed with standardized head orientation and verified in multiplanar reformats.

Airway segmentation

Nasopharynx (hard-palate plane to C1), oropharynx (posterior nasal spine [PNS]–odontoid plane to antero-inferior C2), and hypopharynx (C2 plane to the superior hyoid margin) were segmented with a semi-automatic region-growing workflow plus manual refinement on axial/coronal/sagittal views using predefined planes.

Airway volume measurement

The nasopharynx was superior at the level of the hard palate (high pharynx level). It was inferior at the first cervical vertebra (C1). At the same time, the oropharynx was delineated with the superior border as the line from the PNS to the odontoid process and the inferior border as the line from the antero-inferior border of the C2 vertebra. The superior border for the hypopharynx was the line from the antero-inferior border of C2, and the inferior border was the horizontal line contacting the most superior margin of the body of the hyoid bone (Figure 1). Total airway volume and minimal cross-sectional area (cm^3) were obtained for each subject for nasopharynx, oropharynx, and hypopharynx (Table 1). The airway was also segmented and outlined with reference lines and measurement points, likely corresponding to the nasopharynx, oropharynx, and hypopharynx (Figure 2).

Cephalometric analysis

Lateral cephalograms were reconstructed from the CBCT data and analyzed manually by the examiner using WebCeph software. All measurements were visually inspected and verified by the examiner using standard diagnostic criteria to minimize error and ensure accuracy. The analysis was fully clinician-driven and not dependent on automated AI-based interpretation.

Skeletal classification

Skeletal Class was defined primarily by ANB (Class I: 0°–4°; Class II: >4°; Class III: <0°) and corroborated by Wit's appraisal (Class I: −1 to +1 cm^3; Class II: > +1 cm^3; Class III: < −1 cm^3). To isolate skeletal-pattern effects independent of extreme mandibular displacement, the mandibular sagittal position was constrained to a normative range (SNB of 78°–82°); subjects outside this window were excluded.

Patient examination

A complete clinical examination was performed to assess skeletal discrepancies and mandibular position. This included medical and dental history, extraoral and intraoral examinations, and evaluation of occlusion and temporomandibular joint function. All findings were recorded using a standardized protocol to reduce examiner bias and ensure consistency among patients.

Volumetric measurements

WebCeph software was used to determine the volume of the nasopharynx, oropharynx, and hypopharynx in cm^3. The key measurements were nasopharynx volume from the back of the nasal cavity to the soft palate, and oropharynx volume from the soft palate to the epiglottis. To ensure consistency in clinical evaluation, CBCT, volumetric measurement, and clinical examination were completed by a single examiner.

Sample size calculation

Power calculations for gender differences estimated a priori for an omnibus test (ANOVA/Kruskal–Wallis) with a medium effect (f=0.25), α=0.05, three groups, and 80% power needed (n=159). Because of resource limitations, this study aimed to recruit 60 patients (20/group), which was considered exploratory with an emphasis on effect sizes and 95% CIs. This estimate can be used to inform a future definitive sample-size calculation.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (IBM, Chicago, USA, version 26). For descriptive statistics, data were presented as numbers, percentages, means ± SD, and 95% CIs. The Shapiro-Wilk test was used to determine the normality of the data. Age was then compared among groups using the Kruskal-Wallis test, while gender and airway morphology distribution were assessed using the Chi-Square test. Airway measurements were compared using the Mann–Whitney U test, with Bonferroni correction applied for three pairwise comparisons (adjusted α = 0.017).

Results

Participant characteristics

Participants' age ranged from 19 to 38 years, with a mean of 28.82 ± 5.87 years and a 95% CI of 27.22–30.4 years. Class I participants were aged 20 - 38 years, with a mean age of 29.10 ± 5.72 years and a 95% CI of 26.42 - 31.78 years. Class II participants were aged 19 to 38 years, with a mean of 29.65 ± 5.90 years and a 95% CI of 26.89 - 32.41 years. In Class III, ages ranged from 19 to 38 years (mean 27.44 ± 6.13 years; 95% CI, 24.17-30.7 years). Gender was equally distributed between the Class I and II groups (12 females and eight males each), while Class III included 11 females (55%) and nine males (45%). The male-to-female ratio was 1.5:1 for Classes I and II and 1.22:1 for Class III. There was no significant difference in age group (p=0.539) or gender distribution (p=0.934) among the classes (Table 2).

Airway volumetric measurements and SMs

For the nasopharynx, the mean volumes for Classes I, II, and III were 8.96±1.55, 7.89±0.96, and 12.97±2.04 cm^3, respectively, with a non-significant reduction in the nasopharyngeal volume in Class I compared to II (p=0.036). At the same time, a noticeable increase in Class III (p<0.001) was observed, showing a prolonged nasopharyngeal space in Class III.

For the oropharynx, the mean volumes for Classes I, II, and III were 9.35± 3.48, 8.61±3.95, and 12.0± 5.48 cm^3, respectively, with no significant differences between Class I and II (p=0.587). In addition, no significant differences were observed between Class II vs. III (p=0.049) and Class I vs. III (p=0.03), with Class III showing greater oropharyngeal space construction, indicating a prolonged airway volume in this Class. The mean volumes for Classes I, II, and III were 9.49±2.97, 7.95±5.03, and 12.28±4.14 cm^3, respectively, in the hypopharynx; the only significant difference was observed between Class II and Class III (p=0.002). Class III had a prolonged hypopharyngeal space, meaning a larger airway volume than Classes I/II (Table 3).

Airway morphology and SMs

In Class I, 18 patients (90%) exhibited normal airway morphology, 2 patients (10%) displayed an elongated airway, and none had a collapsed airway. In Class II, 16 patients (80%) had a normal airway, 3 patients (15%) had a collapsed airway, and 1 patient (5%) had an elongated airway. In Class III, 12 patients (60%) had a normal airway, 1 (5%) had a collapsed airway, and 7 (35%) had an elongated airway. The analyses between Class I and II and between Class I and III did not reach statistical significance (p>0.05), whereas the analysis between Class II and Class III was significant (p=0.048) (Figure 4 and Table 4).

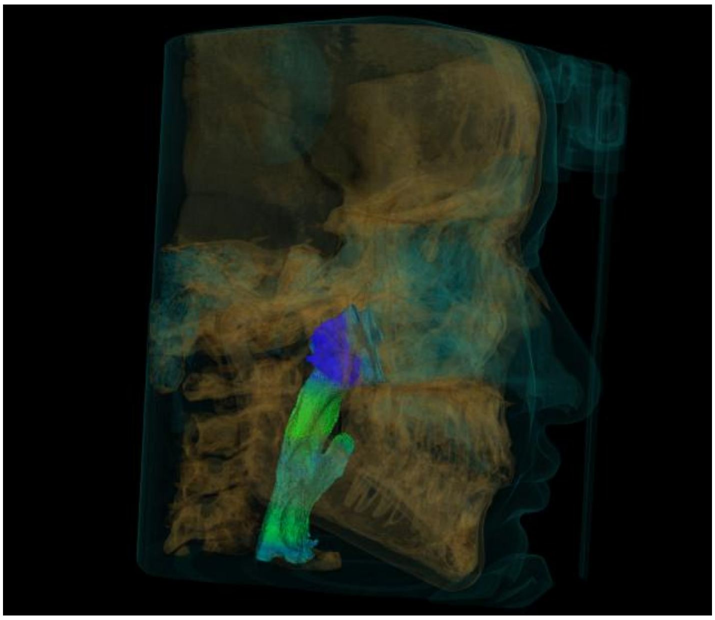

Figure 1: Sagittal Three-Dimensional Cone Beam Computed Tomography (CBCT) image of class I upper airway anatomy presents a patient's upper airway anatomy with a Class I skeletal relationship, characterized by ordinary anteroposterior alignment in the maxilla and mandible.

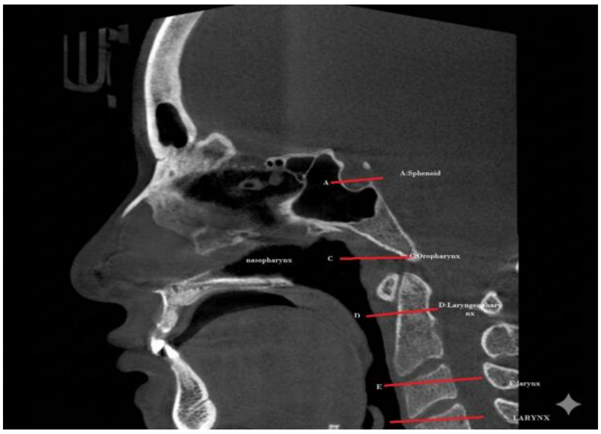

Figure 2: Three-dimensional cone beam computed tomography (CBCT) reconstruction of a patient with a Class II skeletal relationship. The airway segments are colour-coded for clarity, distinguishing the nasopharynx, oropharynx, and hypopharynx. The Class II profile typically features a protruded maxilla, which may impact airway patency. The anatomical landmarks used for determining upper airway volume are identified as follows: point A represents the center of the sphenoid, point B indicates the nasopharynx, region C denotes the oropharynx, region D identifies the hypopharynx, and point E marks the larynx. All these identified points are utilized in the calculation of the total upper airway volume.

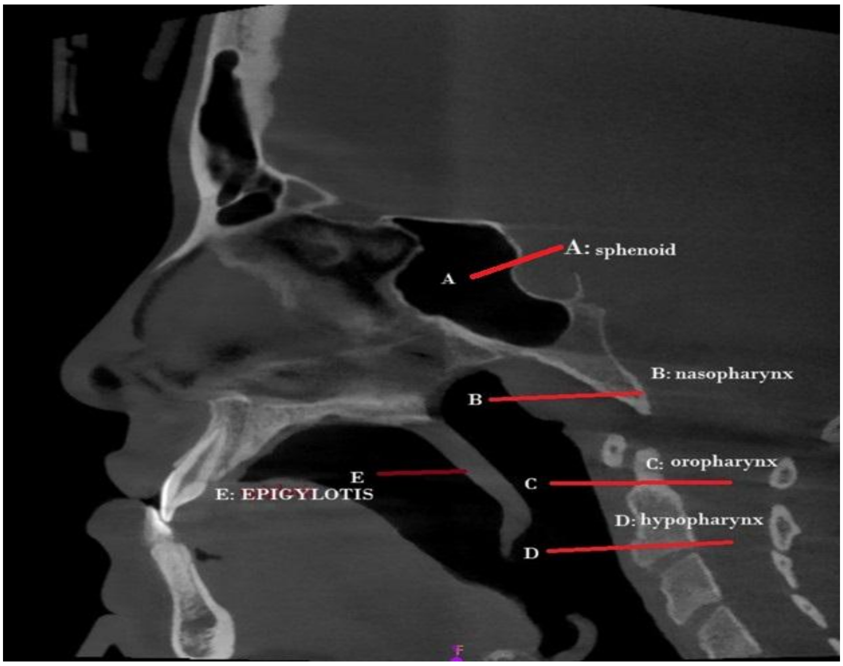

Figure 3: Three-dimensional cone beam computed tomography (CBCT) construction of a patient with a Class Ill skeletal relationship. The Class III profile typically features a retrud maxilla, which may impact airway patency. The anatomical landmarks used for airway volume measurement are identified as follows: point A represents the centre of the sphenoid (which is not included in the upper airway volume calculation), point B indicates the nasopharyngeal region, region C denotes the oropharyngeal area, region D identifies the hypopharyngeal region, and point E marks the epiglottis. All these identified points are utilized in the measurement of the total airway volume.

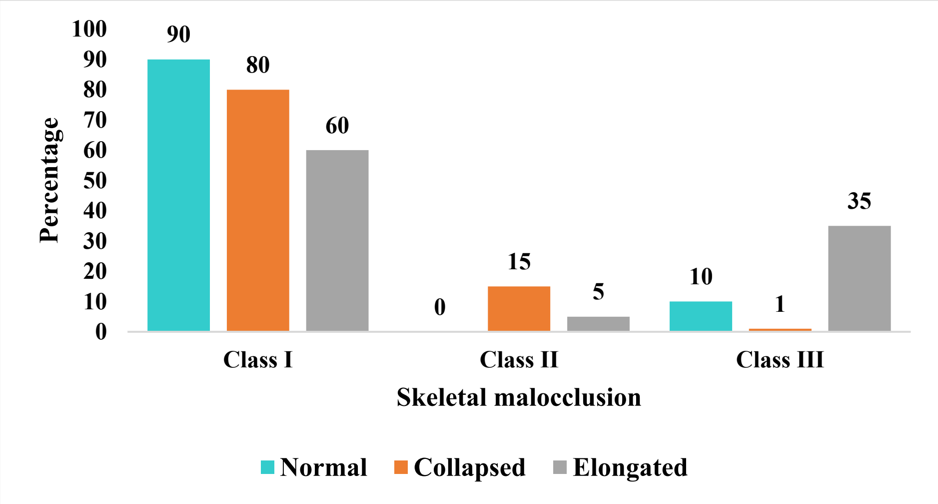

Figure 4: Shows airway morphology across skeletal malocclusion classes.

Table 1: Anatomic landmarks of the upper airways[24].

	Superior Limit	Inferior Limit
Oropharynx	Line extending from the PNS to the tip of the odontoid process.	Line extending from the antero-inferior border of the C2 vertebra.
Hypopharynx	Line extending from the antero-inferior border of the C2 vertebra.	Line extending from the horizontal line coming into contact with the most superior margin of the body of the hyoid bone.

Table 2: Sociodemographic features of the research sample (N=60).

Sociodemographic characteristic			**Skeletal malocclusion**			**Statistics**
			Class I (N=20)	**Class II (N=20)**	**Class III (N=20)**	
Age	Minimum		20	19	19	p= 0.539 ns η2= 0.024
	Maximum		38	38	38	
	Mean		29.10	29.65	27.44	
	SD		5.72	5.90	6.13	
	95% C I		26.42 – 31.78	26.89 – 32.41	24.17 – 30.70	
Gender	Male	N	12	12	11	p= 0.934 ns V= 0.048
		%	60	60	55	
	Female	N	8	8	9	
		%	40	40	45	
Male to Female Ratio			1.5 to1	1.5 to 1	1.22 to 1	

N: Number; %: Percentage; ns: no significant difference; Cramer's V effect size; η2: eta-squared for ANOVA; CI: Confidence Interval; SD: Standard Deviation.

Table 3: Airway volume data across skeletal malocclusion categories (N=60).

Airway measure (cm^3)		Skeletal malocclusion			Statistics		
		Class I (N=20)	Class II (N=20)	Class III (N=20)	I vs II	I vs III	II vs III
Nasopharynx	Mean	8.96	7.89	12.97	p=0.036*	p<0.001*	p=0.001*
	SD	1.55	0.96	2.04	r=0.33	r=0.81	r=0.86
Oropharynx	Mean	9.35	8.61	12.00	p=0.587 ns	p=0.030*	p=0.049*
	SD	3.48	3.95	5.48	r=0.09	r=0.34	r=0.31
Hypopharynx	Mean	9.49	7.95	12.28	p=0.044 ns	p=0.033*	p=0.002*
	SD	2.97	5.03	4.14	r=0.32	r=0.34	r=0.48

N: Number; SD: Standard deviation; *: statistically significant; ns: No significant difference; r: Mann-Whitney U effect size; cm: Centimeter. After Bonferroni correction (adjusted α = 0.017 for three pairwise comparisons).

Table 4: Distribution of airway morphology across skeletal malocclusion classes (N=60).

Airway morphology		Skeletal malocclusion			Statistics		
		Class I (N=20)	Class II (N=20)	Class III (N=20)	I vs II	I vs III	II vs III
Normal	N	18	16	12	p=0.178 ns V=0.294	p=0.083 ns V=0.353	p=0.048* V=0.390
	%	90%	80%	60%			
Collapsed	N	0	3	1			
	%	0	15%	5%			
Elongated	N	2	1	7			
	%	10%	5%	35%			

N: Number; %: Percentage; ns: no significant difference; *: significant difference; V: Cramer's V effect size; After Bonferroni correction (α = 0.017 for three pairwise comparisons).

Discussion

The relation between craniofacial morphology and UA measurements has arisen an outstanding interest in orthodontics, maxillofacial surgery, and sleep medicine[8]. Notably, SM, dental arch structure, and maxillomandibular alignment affect the volume and morphology of the UA[11]. Sagittal skeletal discrepancies, or those related to Class I, II, and III SM, affect airway size and shape through displacement of a posteriorly positioned mandible, maxilla, and associated soft tissues [12]. However, the CBCT has revolutionized the examination of these relationships through high-resolution 3D imaging of skeletal and soft-tissue structures. Also, CBCT is instrumental for measuring the aerodynamics of the craniofacial system that cannot be seen with traditional radiographs. Many studies have used CBCT to evaluate associations between individual skeletal malocclusion and nasopharyngeal, oropharyngeal, and hypopharyngeal size, as well as shape descriptors, such as elongated or collapsed airway[12,13]. Also, patients with a normal sagittal mandibular position may have problems with airway volume and morphology, dependent on skeletal classification. This emphasizes the importance of examining airway parameters not only in retrognathic/prognathic populations, but also in those without marked mandibular sagittal displacement[14].

This study aimed to compare volumetric UA measurements across different SM classes in a normal mandibular position using CBCT. Consequently, nasopharyngeal, oropharyngeal, and hypopharyngeal volumes were compared across the three SM classes (I, II, and III), and airway morphology types (normal, collapsed, and elongated) were analyzed within these classes. The mean participant age in this study was 28.82 ± 5.87 years, with no significant differences among the classes (p=0.422); therefore, age is not a confounding factor in these results. Although airway dimensions can vary with age, the age ranges across groups were similar, suggesting that any age-related bias was minimized. The male and female rates were nearly equal across classes (p=0.934), and the male:female ratio was similar across all groups, indicating that this population was not gender-biased. The age and sex distributions did not differ significantly between the SM classes, suggesting that these findings are valid. The minimal differences in age and gender between the groups would provide greater assurance that airway measurements and morphological differences are attributable to SM rather than to demographic differences. This homogeneity lends confidence to these conclusions, indicating that differences in airway structure are predominantly SM-dependent and minimally affected by age or gender. For instance, Ronen et al. studied the gender and age roles in the development of UA length and explained that although UA dimensions are known to be affected by age and gender; especially after the onset of puberty; muscle-nerve sectioning studies demonstrate that this can be dependent on both age and gender combination and that its effect should be controlled in study design to differentiate their influence from other variables, such as SM. This study minimizes potential confounding effects by demonstrating that there are no significant differences in age or gender among the groups[15].

The primary study's finding was a significant difference in airway volumetric measurements in the SM classes. For Class III, the mean volumes were significantly larger in the nasopharynx than in Class I and Class II. These results are consistent with and discordant with the literature. Recent methodological advancements employing quadrant-based experimental designs have introduced controlled ambiguity, enabling researchers to challenge and reconsider long-standing theoretical assumptions. Sfondrini et al. (2024) found that, by cephalometric analysis, the nasopharyngeal length and depth were shorter in most of the Class III SM patients compared to other classifications. They also concluded that Class III patients had significantly shorter superior pharyngeal airway space than Class II patients. In contrast, Class I patients had significantly shorter mean airway spaces than Class II patients[16].

In contrast, another group noted that the nasopharyngeal, oropharyngeal, and Class III hypopharyngeal volumes were greater than those in Classes I and II[17]. This disparity may be due to differences in methods (cephalometric analysis and volumetric measures), populations, and ethnicity. The inclusion of volumetric measurements in this study may allow for a better characterization of the airway space than linear cephalometric measurements.

Rodrigues et al. (2024) studied Class II and III SM to show their impact on the pharyngeal airway. Their findings were based on extremely small sample sizes, rather than on direct data analysis, the findings showed that patients with Class III malocclusion had significantly larger volume and area measurements than Class II[1]. This correlates with our findings of larger nasopharyngeal, oropharyngeal, and hypopharyngeal volumes in Class III subjects. Similarly, Ahmed et al. (2024) showed that treatment of Class II SM with functional appliances, such as the Frankel II, resulted in a significant increase in UA volume, supporting the idea that airway patency is directly related to skeletal positioning[18]. In contrast, Anis et al. (2026) found no significant difference in oropharyngeal airway volume across SM classifications. However, they noted discrepancies concerning sex for the regional airway area[19].

Furthermore, Oğuz et al. (2025) emphasized the role of vertical growth patterns in airway morphology, noting that hyperdivergent individuals, often associated with Class II skeletal malocclusion, tend to have lower airway volumes [20]. This supports the reduced airway dimensions observed in our Class II group and underscores the multifactorial nature of airway constriction, involving both sagittal and vertical skeletal relationships. The morphologic differences noted in the current study, specifically a greater number of long airway phenotypes in Class III components and a greater number of collapsed phenotypes in Class II, are in line with another study that identified the influence of skeletal malocclusion on UA morphology.

Sana et al. (2022) found that the superior pharyngeal airway of Class III subjects was significantly longer than usual, even after correcting for the acute anteroposterior advancement of the mandible and maxillofacial structures, indicating that the posterior airway space elongation is allowed by the anterior displacement of the mandible and maxillofacial structures[21]. They also noted a tendency toward airway collapse with Class II profiles, particularly in hyperdivergent patients, where skeletal features predispose the mandible to an apparent position and narrow the oropharyngeal segment. Similarly, Ravelo et al. (2020) showed that Class II SM had a reduced pharyngeal airway space and a minimum cross-sectional area, suggesting a structural predisposition to functional impairment[12]. Similar findings were reported by Rodrigues et al. (2025, which showed that Class III subjects continuously displayed the widest nasopharyngeal and/or oropharyngeal areas, while Class

II showed distinctly reduced airway dimensions[22].

The observation of between-group differences in the correlation of skeletal positioning with airway morphology supports the anatomical dependence of airway form on sagittal skeletal positioning. It suggests that skeletal discrepancies may predispose to specific airway shapes with functional consequences. Tseng et al. (2021) demonstrated that pharyngeal airway volume varies significantly across skeletal classes I, II, and III, with class III subjects presenting the largest dimensions and class II the smallest. These findings corroborate the results of the present study, highlighting that sagittal skeletal discrepancies exert a measurable influence on pharyngeal airway morphology[23]. Also, Zheng et al. (2017) demonstrated UA asymmetry in Class III SM with mandibular deviation. It also highlighted the close relationship between various craniofacial skeletal features and the pharyngeal airway space revealed by 3D imaging. Thus, the intricate nature of the airway and its direct correlation to craniofacial skeletal differences was stated[7].

This study has several limitations. First, its cross-sectional design precludes causal inference and allows identification of associations only at a single time point. Second, the sample size was relatively small, which may reduce statistical power and limit generalizability, particularly after adjustment for multiple comparisons. Third, because each scan was measured only once, formal intra-examiner reliability could not be assessed, a limitation to consider when interpreting the precision of the measurements. Finally, the study included only adults; therefore, the findings cannot be generalized to growing patients.

Conclusion

Class III malocclusion was related to significantly increased nasopharyngeal volumes compared to Class I and II, and significantly increased hypopharyngeal volumes compared to Class II. Although oropharyngeal differences were observed at the conventional 0.05 level, they did not remain significant after Bonferroni correction. Class III also demonstrated a higher frequency of airway elongation. Skeletal malocclusion should be considered when assessing airway status and planning orthodontic treatment, particularly in Class II cases, which are at higher risk of airway narrowing. Subsequent studies should investigate the potential dynamic and functional consequences of airway variation using measures such as polysomnography or airflow analysis.

Declarations

Ethics Approval and Informed Consent (Institutional Review Board) Statement: The study protocol was reviewed and approved by the Ethical Committee of the College of Dentistry, University of Sulaimani, Sulaymaniyah, Iraq (No. 24-257 dated December 16, 2024). The study was conducted in accordance with the Declaration of Helsinki. Participants' written informed consent was obtained before the research, and they were free to withdraw at any time.

Author Contributions: KTT: Investigation, data curation, formal analysis, validation, visualization, writing—original draft preparation, writing—review and editing, project administration, manuscript submission, correspondence with the journal, response to editors' and reviewers' comments, Writing and editing.

RAJ: Conceptualization, methodology, and reviewing.

All authors have read and agreed to the published version of the manuscript.

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Additional information: No additional information is available for this paper.

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