Original Article

Study of Pharyngeal Airway Morphology with CBCT: Benefits of Four Premolar Extraction Orthodontic Treatments

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Abstract

Background and Aim: Four premolars extractions are routine procedures for correction of malocclusion, but will inevitably lead to a reduction of tongue space, whether this will weaken the pharyngeal airway remains a controversy. **Patients and Methods:** Cone-beam computed tomography (CBCT) radiographs of 80 patients who completed four premolar extraction orthodontic treatments were collected and divided into three anteroposterior skeletal groups according to the ANB (angle subspinale to nasion to supramentale) value. Linear, angular, cross-sectional area, and volumetric dimensions of the pharyngeal airway were measured using Dolphin Imaging 11.9 software. One-way analysis of variance and Pearson's correlation coefficient test were performed to assess the intergroup comparisons. Treatment changes were evaluated with two-sample t-tests. **Results:** In intergroup comparisons, vertical linear and cross-sectional area differences were identified in S-Go/N-Me, VD1, VD1/N-Me, VD2/N-Me, AA, OAA and OMINI ($p<0.05$), while other measurements showed no significant differences. Angle2, the tilting degree of the pharyngeal airway, showed a positive correlation with ANB ($p<0.05$). As for the treatment changes, a significant increase was found in the pharyngeal airway in the Class I group (OUA $p<0.05$, VD1 $p<0.001$, VD2 $p<0.05$) and Class II group (VD1 $p<0.001$. VD2, $p<0.05$), and inversely, a significant decrease was found in the pharyngeal airway in the Class III group (OAA $p<0.05$, OMINI $p<0.05$, OUA $p<0.05$). No volumetric difference was identified. Interestingly, regarding the preoperative pharyngeal airway size, values trended to the mean value significantly. **Conclusion:** Four premolar extraction orthodontic treatments did not affect the pharyngeal airway volume except for the vertical liner and cross-sectional area dimensions. The trend of the gold standard suggested a positive influence of four premolar extraction orthodontic treatments.

Keywords: *Pharyngeal airway, CBCT, Four premolar extraction*

Introduction

Orthodontists, oral and maxillofacial surgeons, and ENT specialists have shown great concern and interest in pharyngeal airway morphology, as well as the changes that come with the treatment concerning management modalities.[1] Severe pharyngeal airway morphology deformation could lead to disturbed breathing function, loss of life quality, and even life-threatening situations.[2] Compared with lateral cephalometric radiographs, cone-beam computed tomography (CBCT) provides a more reliable, reproducible, and high-quality 3D reconstruction of the pharyngeal airway structure. Given the advantages of the high accuracy of 3D

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analysis and the relatively low dose of radiation, CBCT has been widely accepted and used for airway analysis in recent years. The detailed anatomy, transverse sections, 3D analysis, and volume of the pharyngeal airway can be evaluated and calculated.[3,4]

In the orthodontics field, diverse studies of the interrelation between airway space and craniofacial patterns have been reported for more than a century, which could be traced back to 1907, when Angle reported a narrow upper airway in a child with a retruded mandible.[5-7] Unbalanced growth and development of the dentofacial and craniofacial structures are reported to cause respiratory disorders.[8] Individuals with specific maxillofacial patterns, such as a small or retruded maxilla and mandible and a vertical maxillary excess with a steep mandibular plane, are more likely to possess a narrower airway and therefore are at higher risk for obstructive sleep apnea.[5,9,10]

Skeletal deformities are common issues that orthodontists deal with, and advancement and setback interventions, operations, and extraction treatments are routine procedures for correction or camouflage of jaw discrepancies. These procedures inevitably change the equilibrium of the surrounding soft tissues, including the pharyngeal airway. Beneficial morphologic changes following mandibular advancement have been reported, but on the other hand, surgical setback of the mandible can induce obstructive sleep apnea (OSA) accompanied by airway narrowing. Four premolar extractions and maximum anchorages will improve individuals' convex profiles and will inevitably lead to a reduction in the arch size, which might encroach on the tongue space; however, whether this will decrease the pharyngeal airway morphology remains a matter of debate owing to the heterogeneity of the evaluation methodology among the included studies.[11] A narrower upper airway size was found to be related to the retraction distance of the incisors.[12,13] However, negative results have also been reported.[14]

Pharyngeal airway characterization and monitoring should be one of the normal considerations for clinicians, and it is worth considering what influence could be exerted on the pharyngeal airway morphology in different skeletal patterns by four premolar extraction treatments. Although accumulated studies have reported morphological changes in the pharyngeal airway following four orthodontic premolar extractions, controversy remains, and it is still difficult to draw accurate conclusions. Major limitations include study design heterogeneity, methodological limitations, and an absence of consensus among the included studies. This study was carried out to evaluate and compare the changes in pharyngeal airway dimensions following four premolar extraction orthodontic treatments among different anteroposterior skeletal groups.

Subjects and Methods

Subjects' records selection

A total of 80 subjects were included in this study, and all subjects completed four premolar extraction treatments in the Affiliated Stomatological Hospital of Nanjing Medical University. Records of all of the subjects were selected based on the following inclusion criteria: (1) full permanent dentition, (2) subjects aged between 14 and 35 years old, (3) subjects completed four premolar extraction treatments, (4) no hypertrophy or surgery history of adenoids or tonsils, (5) no orthognathic surgery or orthopedic treatment, and (6) no obvious craniofacial deformities. This study was approved by the Ethical Committee Department, Affiliated Hospital of Stomatology, Nanjing Medical University (PJ2018-066-001). Informed consent was obtained from all participants. Patients were divided into three anteroposterior skeletal pattern groups: Class I group ($0.7 <$ ANB <4.7), Class II group (ANB ≥ 4.7), and Class III group (ANB ≤ 0.7). The sample distribution information is shown in Table 1.

CBCT images

All subjects were instructed to sit in an upright position with the Frankfort horizontal plane parallel to the ground, and their teeth remained occluded. A 360° CBCT scan was acquired using a Computerized Tomography X-ray System (New Tom VG, QR s.r.l., Italy) in the pre-(T0) and post-(T1) orthodontic treatment with the exposure settings of 110 kVp, 0.7 mA, 3.6 s time, 0.3 mm voxel thickness, and 16 cm × 18 cm field of view. The CBCT data were imported and analyzed by Dolphin imaging 11.9 (Patterson, USA).

Linear, angular, sectional cross-sectional area and volumetric measurements

Orientation calibration, 3D reconstructions, and measurements were undertaken by one examiner. Orientation calibration of the 3D head position was conducted using an orientation module and was then rechecked in the axial, sagittal, and frontal slices. The Frankfort plane was parallel to the horizontal line, the coronal plane matched the line passing through the inferior orbital rims of both sides, and the mid-sagittal plane matched the face midline. Three-dimensional reconstructions and measurements of the pharyngeal airway were conducted using a sinus/airway module. The scope of the pharyngeal airway was delineated on the mid-sagittal plane by leaving seed points and identifying four stable anatomical landmarks: the highest point of the anterior upper edge of the Sella center (S), the most superior point of the anterior edge of the first cervical vertebra (C1), the anterior upper edge of the fourth cervical vertebra (C4), and the most inferior point of the hyoid arch (H) [Figure 1a]. The recommended Hounsfield unit values are −210 to −240 for the pharyngeal airway, and the 3D reconstruction was automatically shaped [Figure 1b]. After confirming that the border of the pharyngeal airway was accurately and fully outlined in the axial, sagittal, and frontal slices, the airway volume could be automatically calculated. The line passing through point C1 and point PNS served as the boundary between the oropharynx and nasopharynx. Point T is the most superior point of the pharynx, and points M1 and M2 are the midpoints of the upper and lower boundaries of the pharynx [Figure 1c]. Nineteen linear, angular, cross-sectional area and volumetric measurements were included [Table 2].

Statistical analysis

Orientation calibration, 3D reconstructions, and measurements of 10 randomly selected subjects were undertaken and reconducted by the same examiner 1 month later. Intraclass correlation coefficient test results ranged from 0.76 to 0.85, indicating good intraexaminer reliability. Statistical analysis was performed using SPSS Statistics 19.0 software (IBM, the United States). One-way analysis of variance (ANOVA) was conducted among the initial parameters of the Class I, Class II, and Class III groups. Pearson's correlation coefficient test was performed to identify any significant relationships among the four measurements (Angle1, Angle2, VD1/N-Me, and VD2/N-Me) and the ANB (angle of A point, Nasion and B point, indicate the relative anteroposterior position between the maxilla and mandible) value. Statistical differences in each measurement between T0 and T1 were examined with two sample t-tests. An alpha value of 0.05 was accepted as the significance level.

Results

Comparison of measurements among different anteroposterior groups

As shown with ANOVA among different anteroposterior groups, four linear measurements (VD1, VD1/N-Me, VD2/N-Me, and S-Go/N-Me) and three cross-sectional area measurements (AA, OAA, and OMINI) showed significant differences ($P < 0.05$), whereas there was no significant difference in the angular and volumetric measurements [Table 3]. Interestingly, among the above quantities, compared with the Class I group, three linear measurements (VD1/N-Me, VD2/N-Me, and S-Go/N-Me) and two cross-sectional area measurements exhibited relatively larger values in the Class III group and smaller values in the Class II group [Table 3].

Correlation analysis between measurements and the ANB value

A statistically positive correlation was found between ANB and Angle2 ($r = 0.33$; $P < 0.005$) [Table 4]. Statistically significant negative correlations were found between ANB and VD1/N-Me ($r = -0.43$; $P < 0.001$) and VD2/N-Me ($r = -0.41$; $P < 0.001$) [Table 4]. No statistically significant correlation was found between ANB and Angle1.

Table 1: Sample distribution by ANB, age, and sex

	Anteroposterior groups		
	Class I (n=30)	Class II (n=35)	Class III (n=15)
ANB (°)	3.0±1.23	6.3±1.12	−1.1±1.23
Age (years)	15.7±4.48	18.1±5.41	18.9±4.45
Female	25 (83%)	27 (77%)	12 (80%)
Male	5 (17%)	8 (23%)	3 (20%)

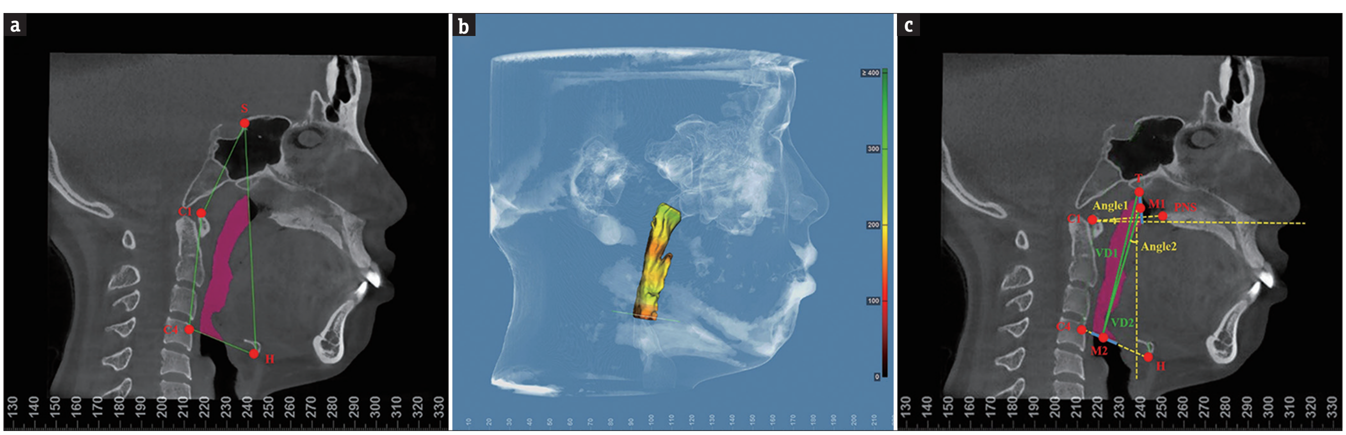

Figure 1: (a) The pharyngeal airway range was defined by four stable anatomical landmarks: points S, C1, C4, and H; (b) the pharyngeal airway was reconstructed in 3D, and the cross-sectional area and volumetric measurements were automatically calculated; and (c) Cephalometric linear and angular measurements of the pharyngeal airway measurements

Table 2: Definitions of linear, angular, cross-sectional area, and volumetric measurements

Measurement	Abbreviation	Definition
Linear measurements		
N-Me (mm)	N-Me	Front face height, the distance between Nasion and Menton
Pharynx airway vertical distance (mm)	VD1	The distance from the highest point of the pharyngeal airway to the midpoint of the lower boundary
Pharyngeal airway vertical distance (mm)	VD2	The distance between the upper and lower midpoints of the pharyngeal airway
S-Go (mm)	S-Go	Back face height, the distance between Sella and Gonion
S-Go/N-Me (%)	S-Go/N-Me	The ratio of back face height to front face height
VD1/N-Me	VD1/N-Me	The ratio of VD1 to the front face height
VD2/N-Me	VD2/N-Me	The ratio of VD2 to the front face height
Angular measurements		
ANB	ANB	The angle between the A point, Nasion, and the B point
Pharyngeal airway horizontal angle (°)	Angle1	Upper boundary horizontal angle of the pharyngeal airway
Pharyngeal airway vertical angle (°)	Angle2	The vertical angle of the line between midpoints of the upper and lower boundary of the pharyngeal airway
Cross-sectional area and volumetric measurements		
Airway area (mm^2)	AA	Sagittal axial area of the pharyngeal airway
Airway lower area (mm^2)	LA	The lower border area of the pharyngeal airway
Airway upper area (mm^2)	UA	The upper border area of the pharyngeal airway
Airway volume (mm^3)	AV	The volume of the pharyngeal airway
Oropharyngeal airway area (mm^2)	OAA	The oropharyngeal airway sagittal axial area
Oropharyngeal airway upper area (mm^2)	OUA	Upper area of the oropharyngeal airway
Oropharyngeal airway volume (mm^3)	OAV	The oropharyngeal airway volume
Oropharyngeal minimum axial area (mm^2)	OMINI	Minimum cross-sectional area of the oropharyngeal airway
Minimum axial area (mm^2)	MINI	Minimum cross-sectional area of the pharyngeal airway

Table 3: Intergroup comparisons among anteroposterior groups

	Anteroposterior groups			*F*	*P*
	Class I	Class II	Class III		
Linear measurements					
N-Me (mm)	124.4±7.00	128.3±6.20	125.1±8.09	2.77	0.07
S-Go/N-Me (%)	66.2±4.09	63.6±103.5	67.5±4.97	5.29	0.007*
VD1 (mm)	69.5±4.65	70.9±5.88	74.5±4.91	4.47	0.02*
VD2 (mm)	58.2±3.51	58.8±3.86	61.0±3.92	2.74	0.07
VD1/N-Me	0.56±0.04	0.55±0.04	0.60±0.0.04	7.32	0.001*
VD2/N-Me	0.47±0.02	0.46±0.03	0.49±0.03	6.74	0.002*
Angular measurements					
Angle1 (°)	3.1±5.86	3.6±5.96	5.8±4.20	0.86	0.43
Angle2 (°)	9.0±5.71	9.9±5.57	6.5±2.65	2.51	0.09
Cross-sectional area and volumetric measurements					
AA (mm^2)	705.2±143.5	658.6±140.01	782.2±175.49	4.05	0.02*
AV (mm^3)	15,094.7±4011.29	14,052.6±3342.62	16,568.7±4301.34	2.37	0.10
LA (mm^2)	277.0±70.38	271.4±78.31	280.6±63.90	0.10	0.91
MINI (mm^2)	143.5±59.54	127.1±42.04	146.7±45.88	1.22	0.30
OAA (mm^2)	603.2±106.83	545.1±120.23	634.3±137.79	3.60	0.03*
OAV (mm^3)	12,675.7±3037.08	11,532.8±2887.51	13,221.7±3533.12	1.99	0.14
OMINI (mm^2)	153.9±49.95	125.4±38.47	144.9±45.84	3.44	0.04*
OUA (mm^2)	203.3±63.75	195.9±65.26	224.1±52.76	1.07	0.35
UA (mm^2)	209.9±100.42	206.6±72.48	258.7±47.87	2.41	0.10

*P<0.05, the difference is statistically significant

Interestingly, the orientation of the pharyngeal airway seemed shaped in a way that fitted in with the anteroposterior skeletal patterns; pharyngeal airway was tilted more backward in the Class II group, whereas the pharyngeal airway was more upright in the Class III group [Figure 2].

Table 4: Correlation of different measurements with ANB

Measurement	Angle1		Angle2		VD1/N-Me		VD2/N-Me	
	R	*P*	*R*	*P*	*R*	*P*	*R*	*P*
ANB	−0.14	0.21	0.33	0.003*	−0.43	0.000***	−0.41	0.000***

***P<0.001, *P<0.05; the difference is statistically significant

Table 5: Changes in the measurements of the pharyngeal airway from T0 to T1

Measurement	T0	T1	Change	Change	*P*
Class I					
Angle1 (°)	3.1±5.86	3.4±5.98	0.3±2.39	9.21%	0.43
Angle2 (°)	9.0±5.71	10.1±5.46	1.1±3.55	11.52%	0.11
LA (mm^2)	277.0±70.38	267.8±76.80	−9.2±61.34	−3.38%	0.42
OAA (mm^2)	603.2±106.83	602.9±173.25	−0.3±125.25	−0.05%	0.99
OAV (mm^3)	12,675.7±3037.08	13,128.3±4763.30	452.6±3499.65	3.51%	0.48
OMINI (mm^2)	153.9±49.95	149.77±59.79	−4.1±45.50	−2.70%	0.63
OUA (mm^2)	203.3±63.75	222.1±62.95	18.8±40.06	8.84%	0.02*
VD1 (mm)	69.5±4.65	71.7±4.50	2.2±2.15	3.12%	0.000***
VD2 (mm)	58.2±3.51	59.9±3.72	1.7±2.61	2.88%	0.02*
Class II					
Angle1 (°)	3.6±5.96	4.3±5.65	0.7±3.81	17.63%	0.31
Angle2 (°)	9.9±5.57	9.6±4.87	−0.2±4.23	−2.05%	0.73
LA (mm^2)	271.4±78.31	256.6±82.83	−14.8±74.90	−5.61%	0.25
OAA (mm^2)	545.1±120.23	527.7±152.62	−17.5±129.03	−3.26%	0.43
OAV (mm^3)	11,532.8±2887.51	11,735.0±4218.78	202.2±3555.92	1.74%	0.74
OMINI (mm^2)	125.4±38.47	122.7±53.10	−2.7±48.53	−2.18%	0.75
OUA (mm^2)	195.9±65.26	188.4±82.01	−7.5±66.42	−3.90%	0.51
VD1 (mm)	70.9±5.88	73.0±4.19	2.0±3.52	2.78%	0.000***
VD2 (mm)	58.8±3.86	60.1±4.00	1.3±3.11	2.19%	0.02*
Class III					
Angle1 (°)	5.8±4.20	5.1±3.87	−0.6±3.52	−11.02%	0.51
Angle2 (°)	6.5±2.65	5.8±3.53	−0.7±3.85	−11.41%	0.48
LA (mm^2)	280.6±63.90	288.4±84.99	7.8±73.66	2.74%	0.69
OAA (mm^2)	634.3±137.79	579.0±128.10	−55.3±70.40	−9.12%	0.0*
OAV (mm^3)	13,221.7±3533.12	12,312.0±3455.58	−909.7±3027.62	−7.13%	0.26
OMINI (mm^2)	144.9±45.84	123.1±42.39	−21.7±35.66	−16.19%	0.03*
OUA (mm^2)	224.1±52.76	199.0±42.74	−25.1±41.86	−11.86%	0.04*
VD1 (mm)	74.5±4.91	74.9±5.66	0.4±1.99	0.54%	0.45
VD2 (mm)	61.0±3.92	61.6±4.28	0.6±2.53	0.98%	0.37

****P*<0.001, **P*<0.05; the difference is statistically significant

Comparison of measurements between T0 and T1 among different anteroposterior groups

After four premolar extraction orthodontic treatments, a significant increase was observed in the Class I group (VD1 $P < 0.001$, OUA $P < 0.05$, VD2 $P < 0.05$) and Class II group (VD1 $P < 0.001$, VD2 $P < 0.05$) [Table 5]. However, a significant decrease was seen in the Class III group (OAA $P < 0.05$, OMNI $P < 0.05$, OUA $P < 0.05$) [Table 5]. The remaining measurements did not show significant differences [Table 5]. Interestingly, the larger values in the Class III group (OAA = 634.3 ± 137.79, OMINI = 144.9 ± 45.84, and OUA = 224.1 ± 52.76) decreased significantly (9.12%, 16.19%, and 11.86%, respectively), and the smaller values in the Class I group (OUA = 203.3 ± 63.75) increased significantly (8.84%) [Table 5]. Compared to the values in the Class III group (VD1 = 74.5 ± 4.91 and VD2 = 61.0 ± 3.92), smaller values in the Class I group (VD1 = 69.5 ± 4.65, and VD2 = 58.2 ± 3.51) increased significantly (3.12% and 2.88%) and the smaller values in the Class II groups (VD1 = 70.9 ± 5.88 and VD2 = 58.8 ± 3.86) increased significantly (2.78% and 2.19%) [Table 5].

Discussion

Removal of four premolars is an imperative and effective treatment approach for correcting malocclusions, improving the appearance, and promoting healthy function of the oral maxillofacial region. Sufficient anatomical dimensional development of the pharyngeal

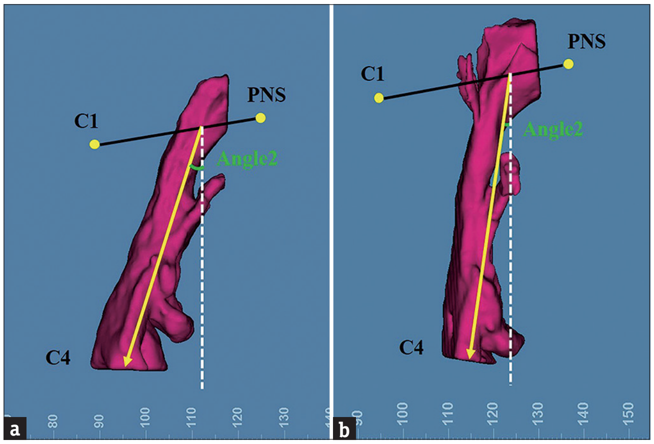

Figure 2: The pharyngeal airway in 3D from two representative subjects. The orientation of the pharyngeal airway shape fitted with the anteroposterior skeletal patterns: (a) the more backward tilt of the pharyngeal airway in the Class II group, (b) a more upright pharyngeal airway in the Class III group

airway is affected by its related structures, such as the tongue and hyoid bone. The mandibular position among different skeletal patterns changes with the position of the hyoid bone and the tongue, which induces adaptations of the pharyngeal airway.[15,16] Accumulated studies have explored the intimate relationship of induced pharyngeal airway dimensions regarding specific skeletal patterns such as hyperdivergent patterns and a retrognathic mandible.[5,17,18] Other findings, including functional research based on computational fluid dynamics, showed that incisor retraction could reduce the pharyngeal airway dimensions.[19,20] In our retrospective analytical study, the linear, angular, cross-sectional area and volumetric dimensions of the pharyngeal airway were measured and compared to evaluate the effect of four premolar extraction orthodontic treatments on the pharyngeal airway dimensions among the anteroposterior skeletal groups. The anteroposterior skeletal pattern was determined and grouped using the measurement of the ANB angle.[21,22]

The measurements were obtained from CBCT taken before and after the comprehensive orthodontic treatment. Mouth-breathing patterns may lead to postural changes and uncontrolled data deviation, so subjects with possible pathogenic factors were excluded, and all included subjects were filmed with the head in a natural position.[23] Longitudinal studies have reported that the growth spurt of the transverse dimension and the sagittal dimension of the pharyngeal airway occurs between 8 and 10 years old and 12 and 13 years old, respectively, in healthy Chinese children.[24] The pharyngeal airway progressively enlarges until adulthood.[25,26] Moreover, previous studies showed no statistically significant differences between growing and adult subgroups regarding the pharyngeal airway dimensions, indicating the limited effect of growth on its dimensions.[19,27] In any event, in our research, off-peak subjects were included, and their age range was 14.2–35.5 to ensure that the pharyngeal airway was mature or close to reaching maturity. The subjects in our study were mostly females in all groups (Class I group: 83%; Class II group: 77%; Class III group: 80%). An MRI retrospective study described a sex difference in the growth pattern of the pharyngeal airway, and the growth velocity considerably slowed 2 years earlier in girls.[28,29] Others demonstrated that the pharyngeal dimensions were larger in men; however, gender difference was not statistically significant in the sagittal skeletal pattern index (ANB), vertical skeletal pattern index Frankfort-mandibular plane angle (MPA), or pharyngeal dimensions.[9,25,27,30] In this study, the female and male subgroups were pooled together and grouped into sagittal skeletal groups (Class I group, Class II group, and Class III group).

The literature suggests that growth may have a slight to no effect on the sagittal depth of the pharyngeal airway, which is primarily established in infancy.[19,31] Furthermore, other studies have shown that there is no statistically significant difference in the depth of the pharyngeal airway among different malocclusion groups.[32,33] For these reasons, in our study, vertical linear measurements were preferred instead of sagittal measurements. Our study showed that the pharyngeal airway volume and morphology were similar among the different malocclusion groups, and the linear (VD1, VD1/N-Me, VD2/N-Me, and S-Go/N-Me) and cross-sectional area (AA, OAA, and OMINI) differences instead of angular and volumetric differences were identified. However, Angle2 (Class I: 9.0 ± 5.71; Class II: 9.9 ± 5.57; Class III: 6.5 ± 2.65) seemed to characterize the orientation of the pharyngeal airway [Figure 2]. Moreover, a positive correlation between Angle2 and ANB was identified [Table 4]. Consistent with reports in the literature, the orientation of the pharyngeal airway fit the anteroposterior skeletal patterns, and the more retrusive the mandible was, the more backward the pharyngeal airway tilted.[34]

It has been reported that compared with untreated individuals, the pharyngeal airway dimensions showed no statistically significant differences after correcting Class I, Class II, and Class III skeletal profiles.[35] On that basis, the influence of pure orthodontic treatment could be partly elucidated. Regarding the effect of orthodontic treatment with four premolar extractions on the pharyngeal airway among different anteroposterior skeletal groups, controversy remains. In our study, after orthodontic treatment with four premolar extractions, a significant increase was observed in the pharyngeal airway in the Class I group (OUA, VD1, VD2) and Class II group (VD1, VD2), and inversely, a significant decrease was observed in the oropharyngeal airway in the Class III group (OAA, OMNI, OUA). A smaller dental arch might contribute to the reduction effect, as the tongue was positioned more posteriorly because of narrowing of the tongue accommodation space. This is supported by research showing that following retraction of the upper incisors, the pharyngeal airway tended to become narrower along with a higher risk of pharyngeal collapse.[12,13,20] The enlargement effect of the posttreatment pharyngeal airway could be explained by the adaption of the pharyngeal airway, which suggested a possible benefit to the patients, especially those with respiratory problems. These increased results in skeletal Class III patients are in agreement with a report of increased superior and middle airway size in subjects with extraction and minimum anchorage.[27] Interestingly, for the preoperative airway size, the relatively larger values decreased and the relatively smaller values increased after orthodontic treatment with four premolar extractions. The Lager values in the Class III group (OAA = 634.3 ± 137.79, OMINI = 144.9 ± 45.84, and OUA = 224.1 ± 52.76) decreased significantly (9.12%, 16.19%, and 11.86%, respectively), and the smaller values in the Class I group (OUA = 203.3 ± 63.75) increased significantly (8.84%). Consistent with the literature, the Class III group had larger pharyngeal airways, and the Class II group had narrower pharyngeal airways than the Class I group.[34,36] Compared to the values in the Class III group (VD1 = 74.5 ± 4.91 and VD2 = 61.0 ± 3.92), the smaller values in the Class I group (VD1 = 69.5 ± 4.65 and VD2 = 58.2 ± 3.51) increased significantly (3.12% and 2.88%, respectively), and the smaller values in the Class II group (VD1 = 70.9 ± 5.88 and VD2 = 58.8 ± 3.86) increased significantly (2.78% and 2.19%, respectively). The values tended to be the gold standard, suggesting a possible positive influence of orthodontic extraction treatment. However, some researchers concluded that the extraction of four premolars did not affect the pharyngeal airway even in bimaxillary protrusion cases.[14,37,38]

Accordingly, pharyngeal airway characterization and monitoring should be taken into routine, careful consideration when planning orthodontic therapy. In our study, we identified that after orthodontic treatment with four premolar extractions, a significant increase was present in the pharyngeal airway in the Class I group (OUA, VD1, and VD2) and Class II group (VD1 and VD2), and inversely, a significant decrease was displayed in the oropharyngeal airway in the Class III group (OAA, OMNI, and OUA). The interesting observation of the trend of the gold standard suggests a possible positive influence of four premolar extraction orthodontic treatments. Further investigations with a larger sample size should be conducted to strengthen the power of the statistical analysis and provide more conclusive scientific evidence.

In conclusion, vertical liner and cross-sectional area differences were identified among different anteroposterior skeletal groups; however, there was no significant difference in the angular or volumetric measurements. There was an observation that Angle2 seemed to characterize the orientation of the pharyngeal airway. Moreover, a positive correlation between Angle2 and ANB was identified. The orientation of the pharyngeal airway shape fitted with the anteroposterior skeletal patterns: the further retrusive the mandible was, the more backward the pharyngeal airway tilted. Four premolar extraction orthodontic treatments did not affect the pharyngeal airway volumetric and angular dimensions except for the vertical liner and cross-sectional area dimensions. The interesting observation of the trend of the gold standard suggests a possible positive influence of four premolar extraction orthodontic treatments.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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