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Original Article

Adaptive Changes in the Posterior Pharyngeal Wall Following Large Retraction of Incisors During Comprehensive Orthodontic Treatment

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Main Points

- The retraction of incisors does not affect the sagittal dimensions of the upper airway.
- The sagittal thickness of the posterior pharyngeal wall decreases significantly as an adaptation to maintain the patency of the upper airway following the retraction of incisors.
- The adaptive changes in the posterior pharyngeal wall occur mainly at the retropalatal and retroglossal regions.
- The adaptive change in the posterior pharyngeal wall can be considered as a risk factor for future sleep-disordered breathing development.

ABSTRACT

Objective: To evaluate the effects of large retraction of incisors on the adaptive changes in the posterior pharyngeal wall and soft palate during comprehensive orthodontic treatment.

Methods: Twenty-seven females with Class I mild crowding or spacing who required non-extraction treatment (group I) and 34 females with Class I bimaxillary dentoalveolar protrusion who required all first premolars extraction for the retraction of their incisors (group II) were included in the study. The effects of non-extraction and incisor retraction following all first premolars extraction orthodontic treatment on the sagittal dimensions of pharyngeal airway passage and posterior pharyngeal wall thickness were evaluated from pre- and post-treatment cephalograms.

Results: The dimensions of pharyngeal airway passage were comparable among the groups. The length of the soft palate increased ($P < .01$) and the thickness of the soft palate decreased ($P < .01$) following retraction of incisors, and the difference between the groups was significant ($P < .05$). The posterior pharyngeal wall thickness was reduced significantly at PPWT2 ($P < .05$), PPWT3 ($P < .001$), PPWT4 ($P < .001$), PPWT5 ($P < .001$), and PPWT6 ($P < .01$) regions following retraction of the incisors, and the difference between the groups was statistically highly significant.

Conclusions: The large retraction of incisors during comprehensive orthodontic treatment in Class I bimaxillary dentoalveolar protrusion malocclusion subjects did not affect the sagittal dimensions of pharyngeal airway passage, but the thickness of the posterior pharyngeal wall reduced significantly as an adaptation to maintain the patency of the upper airway.

Keywords: Bimaxillary protrusion, incisor retraction, pharyngeal airway passage, upper airway, pharyngeal wall thickness, sleep-disordered breathing

INTRODUCTION

Extraction of all first premolars and retraction of incisors is a well-established treatment option for the management of Class I bimaxillary dentoalveolar protrusion malocclusions. The retraction of incisors leads to a reduction of oral volume and the available space for the accommodation of the tongue.[1,2] This often leads to the posterior position of the tongue and reduction of pharyngeal airway passage (PAP) dimensions.[3] Though this proposed mechanism is theoretically acceptable, the reduction of PAP dimensions following retraction of incisors is still

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controversial. There are many studies in the literature supporting the reduction of PAP dimensions and volume following retraction of incisors.[4-12] However, a lot of studies also reported no changes in the PAP dimensions after the retraction of incisors.[1,13-16] Although the evaluation of upper airway dimensions by using three-dimensional images is considered the best method, the results are conflicting.[5,14] One study reported extraction orthodontic treatment leads to adaptive changes in the upper airway morphology.[14] As the changes in the upper airway dimensions following extraction orthodontic treatment are confusing and controversial,[1,4-16] there might be compensatory adaptations in the surrounding soft tissue. To the best of our knowledge, there is no study evaluating the adaptive changes in the surrounding soft tissue of the upper airway following maximum retraction of the incisors. Thus, the present study was designed to evaluate the effects of retraction of incisors on the sagittal thickness of the posterior pharyngeal wall among the subjects with Class I bimaxillary dentoalveolar protrusion malocclusions.

METHODS

This retrospective study was conducted in the Division of Orthodontics, Department of Dentistry, All India Institute of Medical Sciences, Bhubaneswar, India. Assuming the mean difference of 0.5 mm in the thickness of posterior pharyngeal wall at the level of oropharynx between the groups, 0.65 mm as standard deviation (SD), 95% Confidence Interval, 80% power, a sample size of 27 in each group was calculated. Open Epi version 3, an open source calculator was used for calculation of sample size. Orthodontic record files of 348 subjects who had completed comprehensive orthodontic treatment between January 2015 and December 2020 were reviewed by one of the authors (AKJ). Of 348, 78 (M = 17, F = 61) subjects met the selection criteria. The inclusion criteria were:

- Age between 18-25 years;
- Class I skeletal relationship;
- Similar vertical facial growth pattern (normodivergent growth; Frankfort mandibular plane angle (FMA), 25˚ ± 5˚);
- Female subjects having Class I malocclusion with mild crowding or spacing (≤4 mm) who were treated by non-extraction treatment;
- Female subjects having Class I bimaxillary dentoalveolar protrusion malocclusions with mild crowding or spacing (≤4 mm) who were treated by all first premolars extraction and had a minimum of 5 mm retraction of maxillary and mandibular incisors; and
- Good quality pre- and post-treatment lateral cephalograms with hard and soft tissue details.

Subjects with a history of comprehensive orthodontic treatment, surgery for pharyngeal pathology and nasal obstruction, snoring, and any systemic disease were excluded.

Of 78 selected subjects, there were only 17 males. Thus, all female subjects (n = 61) were included in the study. Of 61 subjects, 27 subjects who had Class I dental malocclusions with mild crowding or spacing (≤4 mm) on Class I skeletal relationship and treated by non-extraction orthodontic treatment were included in Group I. Group II included the rest of the 34 subjects who had Class I bimaxillary dentoalveolar protrusion malocclusions with mild crowding or spacing (≤4 mm) on Class I skeletal relationship and treated by all first premolars extraction for the retraction of their anterior teeth. Written informed consent had been obtained from each patient for the comprehensive orthodontic treatment and to use their records for various academic and research activities. The present study was approved by the Institute Ethics Committee (T/IM-NF/Dentistry/20/151) and was conducted according to the principles of the Helsinki Declaration.

All the subjects selected for the study had been treated by the same operator (AKJ). The malocclusion in all subjects was corrected by a standard edgewise appliance system (0.018" slot, American Orthodontics, Sheboyan, WI, USA). In Group II subjects, anchorage in the maxillary and mandibular arches was reinforced by the Nance button and lingual arch, respectively, and 2 steps space closure technique was followed. In all subjects, the cephalograms were recorded before the beginning and 1 week after the completion of comprehensive orthodontic treatment. All cephalograms were recorded with the same machine (NewTom GiANO, Imola, Bolanga, Italy) with the same exposure parameters (80 Kvp, 10 mAs, and 1.6 seconds). While recording the lateral cephalograms, subjects were placed in the standing position with Frankfort horizontal plane parallel to the floor and teeth in centric occlusion. The heads of the subjects were kept erect. The cephalograms were exposed at the end-expiration phase of the respiration. Subjects were instructed not to move their heads and tongues and not to

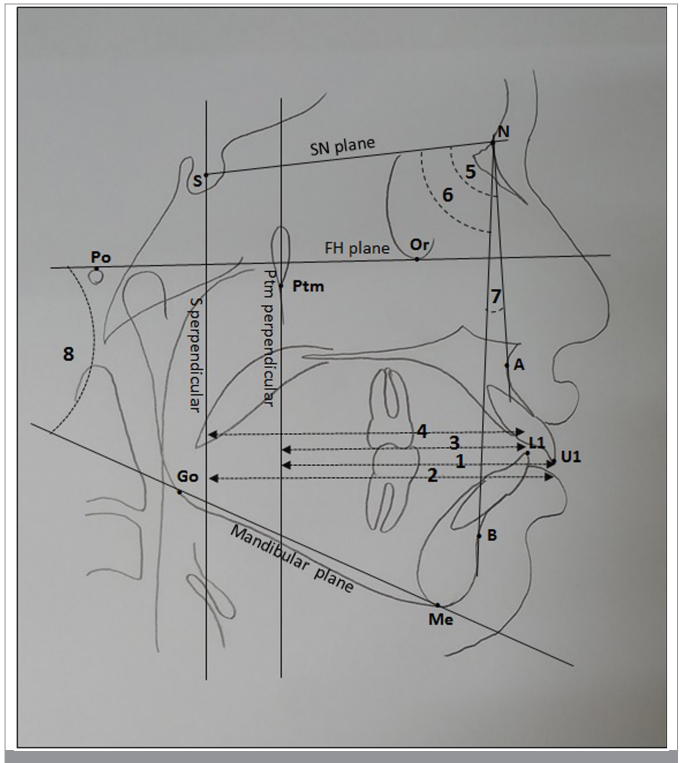


Figure 1. Cephalometric landmarks, reference planes, and linear and angular parameters used for the evaluation of sagittal and vertical jaw relationships and the amount of incisor retraction

swallow during the exposure of cephalograms. All the lateral cephalograms were traced manually by the same evaluator (AKJ).

The method for the evaluation of sagittal and vertical jaw relationships and the amount of maxillary and mandibular incisors retraction are shown in Figure 1. The landmarks were sella (S), nasion (N), porion (Po), orbitale (Or), gonion (Go), Point A (A), Point B (B), menton (Me), pterygomaxillary fissure (Ptm), the tip of upper incisor (U1), and the tip of the lower incisor (L1). The reference planes included SN plane, the line joining S and N; FH plane, the line joining Po and Or; Ptm perpendicular, the perpendicular plane on FH plane at Ptm; S perpendicular, perpendicular plane on FH plane at S; and mandibular plane, the line joining Go and Me. The linear parameters included (1) U1 to Ptm perpendicular, the perpendicular distance from U1 to Ptm perpendicular; (2) U1 to S perpendicular, the perpendicular distance from U1 to S perpendicular; (3) L1 to Ptm perpendicular, the perpendicular distance from L1 to Ptm perpendicular; (4) L1 to S perpendicular, the perpendicular distance from L1 to S perpendicular. The angular parameters considered were (5) SNA, the angle between S, N, and A; (6) SNB, the angle between S, N, and B; (7) ANB, the angle between A, N, and B; (8) FMA, the angle between the FH plane and the mandibular plane.

The sagittal dimensions of PAP were determined according to the method described in previous studies[17,18] and mentioned in Figure 2. The cephalometric landmarks included N, Po, Or, posterior nasal spine (PNS), Ptm, basion (Ba); the tip of soft palate (U), upper pharyngeal wall (UPW), the intersection of line Ptm-Ba and posterior pharyngeal wall; middle pharyngeal wall (MPW), the intersection of perpendicular line on Ptm perpendicular from U with the posterior pharyngeal wall, vallecula (V), and lower pharyngeal wall (LPW), the intersection of perpendicular line on Ptm perpendicular from V with the posterior pharyngeal wall. The FH plane, Ptm perpendicular, and Ba-N plane, the line joining Ba and N were considered as reference planes. Various linear parameters included (1) DNP (Ptm-UPW); (2) HNP, the shortest linear distance from PNS to Ba-N plane; (3) DOP (U-MPW); (4) DHP (V-LPW); (5) soft palate length (SPL) (U-PNS); (6) soft palate thickness (SPT), the maximum thickness of the soft palate. The angular parameter included (7) soft palate inclination (SPI) (Ptm perpendicular × PNS-U), the angle between Ptm perpendicular and the soft palate (PNS-U).

The posterior pharyngeal wall thickness (PPWT) was evaluated according to the method mentioned by Ghodke et al.[18] and Joseph et al.[19] (Figure 3). Various landmarks were anterior nasal spine (ANS), PNS, mid-point of soft palate (MSP; it is the intersection of PNS-U line and a line representing the maximum thickness of soft palate); U, Go, Me, superior-anterior point of C3 vertebra (SC3); inferior-anterior point of C3 vertebra (IC3). Reference planes were (1a) palatal plane (ANS-PNS), (2b) mandibular plane, (3c) anterior tangent to C2 vertebra, a tangent is drawn along the anterior border of C2 vertebra; (4d) the long axis of the soft palate (PNS-U). The linear parameters included (1) PPWT1, the distance from the intersection point of palatal plane and posterior pharyngeal wall to the intersection point of palatal plane and anterior tangent of C2 vertebra; (2) PPWT2, the distance from the intersection point of the line parallel to

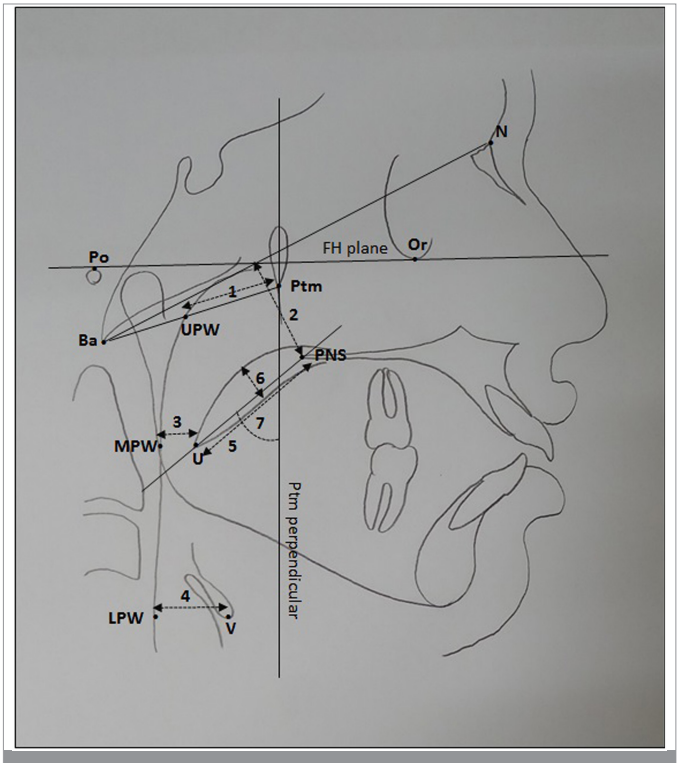


Figure 2. Cephalometric landmarks, reference planes, and linear and angular parameters used for the evaluation of sagittal pharyngeal airway passage dimension changes

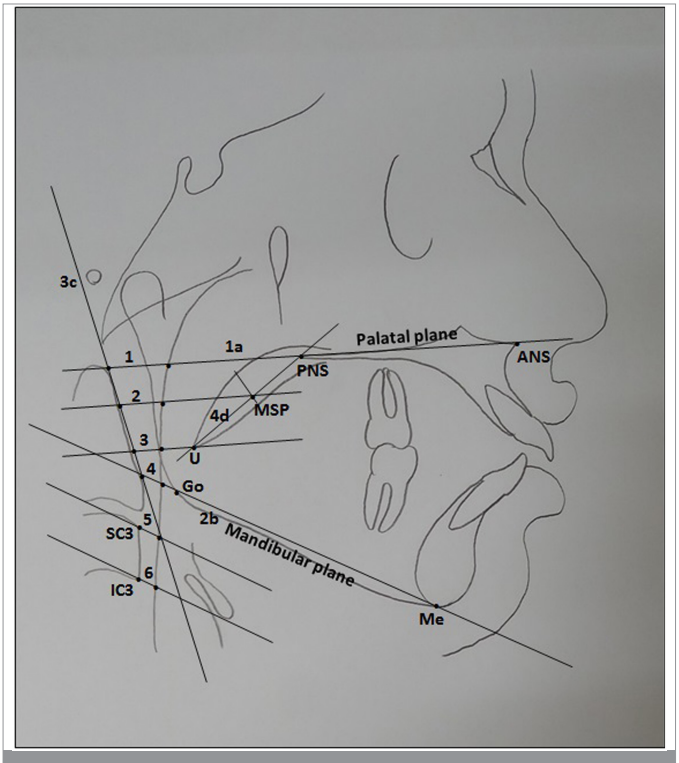


Figure 3. Cephalometric landmarks, reference planes, and linear parameters used for the evaluation of posterior pharyngeal wall thickness change

the palatal plane passing through U and the posterior pharyngeal wall to the intersection point of the same line extended posteriorly and anterior tangent of C2 vertebra; (3) PPWT3, the distance from the intersection point of the line parallel to the palatal plane passing through U and the posterior pharyngeal wall to the intersection point of the same line extended posteriorly and anterior tangent of C2 vertebra; (4) PPWT4, the distance from the intersection point of the mandibular plane and posterior pharyngeal wall to the intersection point of the mandibular plane and anterior tangent of C2 cervical vertebra; (5) PPWT5, the distance from the intersection point of the line parallel to the mandibular plane passing through the superior-anterior point of C3 vertebra and the posterior pharyngeal wall to superior-anterior point of C3 vertebra; (6) PPWT6, the distance from the intersection point of the line parallel to mandibular plane passing through the inferior-anterior point of C3 vertebra and the posterior pharyngeal wall to inferior-anterior point of C3 cervical vertebra.

The linear magnifications of radiographs were corrected and calibrated according to the magnification factor, using the radio-opaque ruler (calibration marker). The linear parameters were measured by digital caliper to the nearest 0.01 mm and protractor to the nearest 0.5˚ degree for the measurement of angular measurements. All the parameters were measured twice and their mean was considered for the statistical analysis. The assessment of intra-observer error and reproducibility of landmark location and measurement errors was analyzed by retracing the 10 randomly selected cephalograms after a gap of 15 days. The intra-observer reliability of the measurements was calculated by the intraclass correlation coefficient (ICC) for the measurements obtained by the evaluator at both times.

Statistical Analysis

All the statistical analyses were performed in the Statistical Package for the Social Sciences software (for Windows 7, version 25, SPSS, Chicago, Ill, USA). Descriptive statistics were used. Shapiro–Wilk's test was used to examine the normality of the data. The significant changes between pre- and post-treatment values in each group were determined by paired *t*-test. Any significant difference in the changes between the 2 groups was evaluated by an unpaired *t*-test. The *P* value of .05 was considered as the level of significance.

RESULTS

The ICC ranged from 0.96 to 0.99 showing excellent reliability between the measurements. The mean age of the subjects at the beginning of treatment was 21.04 ± 2.08 years and 22.50 ± 3.53 years in Group I and II subjects, respectively ($P = .922$). The mean duration of treatment was 405.96 ± 124.32 days in Group I and 794.5 ± 105.35 days in Group II subjects ($P < .001$). The mean body mass index (BMI) in Group I subjects was 25.16 ± 1.89 kg/m^2 at the beginning and 24.87 ± 1.72 kg/m^2 at the end of treatment ($P = .184$), whereas it was 24.91 ± 1.99 kg/m^2 and 24.78 ± 1.86 kg/m^2 at the beginning and end of treatment, respectively, in Group II subjects ($P = .100$). The mean BMI of the subjects among Group I and II subjects at the beginning ($P = .638$) and end of the treatment ($P = .846$) was comparable. Various parameters for the sagittal and vertical skeletal jaw relationships and the mean retraction of the maxillary and mandibular incisors are mentioned in Table 1. The mean change of SNA, SNB, ANB, and FMA was very minimum during the treatment in each group and the mean differences were statistically comparable. The mean forward or backward movement of upper and lower incisors during the treatment was very minimum in Group I subjects. In Group II subjects, the mean retraction of the upper and lower incisors in relation to the Ptm perpendicular was 6.39 ± 1.18 mm and 5.77 ± 1.26 mm, respectively, and in relation to the Sella (S) perpendicular, it was 6.69 ± 1.67 mm and 6.24 ± 1.47 mm, respectively.

The sagittal PAP dimension changes are described in Table 1. In Group I subjects, non-extraction orthodontic treatment had no significant effect on sagittal PAP dimensions and soft palate. In Group II subjects, incisor retraction did not affect sagittal PAP dimensions, but it had a significant effect on the length ($P < .01$), thickness ($P < .01$), and inclination ($P < .05$) of the soft palate. The SPL increased from 31.67 ± 4.07 mm to 32.64 ± 3.73 mm following the retraction of incisors ($P = .003$). The SPT decreased from 8.60 ± 1.41 mm to 7.66 ± 1.28 mm ($P = .001$) and the SPI increased from 41.76˚ ± 6.10˚ to 43.26˚ ± 5.60˚ ($P = .041$) by the retraction of incisors in Group II subjects. Between the groups, the comparison showed a significant difference in the changes of SPL and SPT ($P < .05$).

The changes in the sagittal thickness of the posterior pharyngeal wall are described in Table 1. In Group I, non-extraction orthodontic treatment had no significant effect on the sagittal PPWT except PPWT4 ($P < .05$), which decreased from 3.07 ± 0.90 mm to 2.51 ± 0.64 mm following the treatment. But in Group II subjects, all the variables related to the measurement of the sagittal thickness of the posterior pharyngeal wall were decreased significantly following the retraction of the incisors except PPWT1. The inter-group comparison showed a statistically significant difference for PPWT2 ($P < .05$), PPWT3 ($P < .001$), PPWT4 ($P < .01$), and PPWT5 ($P < .001$) changes.

DISCUSSION

There are many diagnostic aids for the evaluation of PAP dimensions and sagittal thickness of the posterior pharyngeal wall. However, lateral cephalograms are the most commonly used one. Miles et al.[20] reported high reliability of cephalometric landmarks and measurements for the same. The commonly used cephalometric landmarks for the evaluation of airway structures can also be reliably identified.[21] Thus, cephalograms are still used widely to evaluate the sagittal dimensions of the upper airway.[17,18,22] The American Association of Orthodontists' white paper on obstructive sleep apnea and orthodontics suggested that 3D evaluation of the upper airway is ideal for the evaluation of upper airway dimensions.[23] However, the primary outcome measure in the present study was to evaluate the sagittal thickness of the posterior pharyngeal wall which is a 2D variable, so lateral cephalograms were considered as an appropriate tool for the same outcome measure.

Table 1. Comparison of skeletal, dental, pharyngeal variables at pre- and post-treatment within groups and comparison of treatment changes between groups

Variables	Group-I (Non-extraction) (n = 27)				Group-II (Extraction) (n = 34)				Comparison of Mean Differences Gr. I vs. Gr. II Significance (*P* value)
	Pre-Treatment Mean ± SD	Post-Treatment Mean ± SD	Difference Mean ± SD	Significance (*P* Value)	Pre-Treatment Mean ± SD	Post-Treatment Mean ± SD	Difference Mean ± SD	Significance (*P* value)	
SNA (°)	82.26 ± 2.04	82.48 ± 1.96	0.22 ± 1.01	0.265 ^{NS}	82.18 ± 1.89	82.26 ± 2.46	0.08 ± 1.35	.707 ^{NS}	.248 ^{NS}
SNB (°)	80.22 ± 1.92	80.56 ± 2.24	0.33 ± 1.41	0.232 ^{NS}	79.59 ± 2.42	80.18 ± 2.71	0.58 ± 1.25	.010*	.460 ^{NS}
ANB (°)	2.00 ± 1.00	1.93 ± 1.26	−0.07 ± 1.10	0.731 ^{NS}	2.59 ± 1.25	2.09 ± 1.21	−0.50 ± 1.05	.009**	.130 ^{NS}
FMA (°)	22.30 ± 1.79	22.48 ± 1.84	0.18 ± 0.96	0.327 ^{NS}	25.41 ± 2.06	25.15 ± 2.06	−0.26 ± 1.37	.271 ^{NS}	.155 ^{NS}
U1-Ptm perpendicular (mm)	54.80 ± 4.24	54.47 ± 4.03	−0.33 ± 2.31	0.465 ^{NS}	57.49 ± 3.69	51.10 ± 3.34	−6.39 ± 1.18	.000***	.000***
U1-S perpendicular (mm)	73.21 ± 4.38	72.52 ± 4.12	−0.69 ± 2.78	0.206 ^{NS}	74.35 ± 5.37	67.65 ± 5.13	−6.69 ± 1.67	.000***	.000***
L1-Ptm perpendicular (mm)	50.70 ± 4.29	51.03 ± 3.94	0.23 ± 3.22	0604 ^{NS}	53.41 ± 4.06	47.64 ± 3.83	−5.77 ± 1.26	.000***	.000***
L1-S perpendicular (mm)	69.30 ± 4.36	69.75 ± 3.81	0.45 ± 2.46	0.347 ^{NS}	70.65 ± 5.38	64.41 ± 5.05	−6.24 ± 1.47	.000***	.000***
DNP (mm) (Ptm-UPW)	21.28 ± 3.09	20.37 ± 3.24	−0.91 ± 2.42	0.062 ^{NS}	19.35 ± 4.58	18.91 ± 5.32	−0.44 ± 2.43	.290 ^{NS}	.034*
HNP (mm) (PNS to Ba-N plane)	21.57 ± 2.24	21.85 ± 2.09	0.28 ± 0.82	0.090 ^{NS}	22.13 ± 2.49	21.82 ± 2.32	−0.31 ± 1.47	.229 ^{NS}	.068 ^{NS}
DOP (mm) (U-MPW)	10.23 ± 2.90	10.20±2.69	−0.03 ± 1.14	0.889 ^{NS}	10.50 ± 3.48	10.27 ± 3.39	−0.23 ± 2.04	.514 ^{NS}	.651 ^{NS}
DHP (mm) (V-LPW)	14.77 ± 2.50	14.94 ± 2.29	0.16 ± 1.70	0.624 ^{NS}	14.72 ± 2.65	14.33 ± 2.23	−0.39 ± 1.65	.179 ^{NS}	.206 ^{NS}
SPL (mm) (U-PNS)	30.96 ± 3.69	30.87 ± 3.28	−0.08 ± 2.22	0.821 ^{NS}	31.67 ± 4.07	32.64 ± 3.73	0.96 ± 1.50	.003**	.040*
SPT (mm) (Maximum thickness of the soft palate)	8.80 ± 1.07	8.61 ± 1.23	−0.18 ± 0.86	0.270 ^{NS}	8.60 ± 1.41	7.66 ± 1.28	−0.94 ± 1.50	.001**	.024*
SPI (°) (Ptm per × PNS-U)	38.41 ± 4.34	38.41 ± 5.64	0.00 ± 3.85	1.000 ^{NS}	41.76 ± 6.10	43.26 ± 5.60	1.5 ± 4.11	.041*	.151 ^{NS}
PPWT1 (mm)	16.16 ± 2.47	16.47 ± 2.41	0.30 ± 2.16	0.468 ^{NS}	16.56 ± 2.17	16.28 ± 2.20	−0.28 ± 2.19	.459 ^{NS}	.300 ^{NS}
PPWT2 (mm)	8.12 ± 0.96	8.06 ± 1.05	−0.06 ± 0.83	0.699 ^{NS}	9.38 ± 2.33	8.44 ± 1.58	−0.94 ± 2.10	.013*	.044*
PPWT3 (mm)	4.12 ± 0.77	3.88 ± 0.77	−0.23 ± 0.66	0.084 ^{NS}	5.23 ± 0.88	3.99 ± 0.91	−1.24 ± 1.14	.000***	.000***
PPWT4 (mm)	3.07 ± 0.90	2.51 ± 0.64	−0.56 ± 1.30	0.033*	4.25 ± 1.27	2.73 ± 0.95	−1.51 ± 1.36	.000***	.008**
PPWT5 (mm)	3.80 ± 0.54	3.92±0.50	0.12 ± 0.55	0.265 ^{NS}	4.71 ± 0.70	3.73 ± 0.52	−0.98 ± 0.70	.000***	.000***
PPWT6 (mm)	3.76 ± 0.70	3.58 ± 0.57	−0.18 ± 0.74	0.204 ^{NS}	4.31 ± 0.65	3.89 ± 0.45	−0.42 ± 0.64	.001**	.188 ^{NS}

*P <.05; **P <.01; ***P <.001.

ANB, angle between "A, " "N, " and "B"; DHP, depth of the hypopharynx; DNP, depth of the nasopharynx; DOP, depth of the oropharynx; FMA, Frankfort mandibular plane angle; HNP, height of the nasopharynx; L1-Ptm perpendicular, perpendicular distance from L1 to Ptm perpendicular; L1-S perpendicular, perpendicular distance from L1 to S perpendicular; NS, non-significant; PPWT1, posterior pharyngeal wall thickness at nasopharyngeal space 1; PPWT2, posterior pharyngeal wall thickness at nasopharyngeal space 2; PPWT3, posterior pharyngeal wall thickness at oropharyngeal space 1; PPWT4, posterior pharyngeal wall thickness at oropharyngeal space 2; PPWT5, posterior pharyngeal wall thickness at hypopharyngeal space 1; PPWT6, posterior pharyngeal wall thickness at hypopharyngeal space 2; SD, standard deviation; SNA, angle between "S," " N, " and "A"; it represents the anteroposterior position of the maxilla in relation to the anterior cranial base; SNB, angle between "S, " "N, " and "B"; it represents the anteroposterior position of the mandible in relation to the anterior cranial base; SPI, soft palate inclination; SPL, soft palate length; SPT, soft palate thickness; U1-Ptm perpendicular, the perpendicular distance from U1 to Ptm perpendicular; U1-S perpendicular, perpendicular distance from U1 to S perpendicular.

The effects of incisor retraction following all first premolars extraction among Class I bimaxillary dentoalveolar protrusion malocclusion subjects on PAP is controversial.[24-26] Few studies reported a decrease in sagittal PAP dimensions following incisor retraction in Class I bimaxillary dentoalveolar protrusion malocclusion subjects.[4-10,12] The retraction of the anterior teeth resulted in the dorsal movement of the anterior boundary of the oral cavity and enforced the tongue backward, resulting in the upper airway diminishing in size, especially in the base of the tongue and next in the back of the soft palate.[4,6,9,13] However, the present study did not find any change in the sagittal PAP dimensions following retraction of incisors, and the changes were also comparable to non-extraction treatment subjects. Similar to the observations of the present study, many previous studies also reported no effect of incisor retraction on the sagittal PAP dimensions among adolescents[11,13,27] and in adults.[1,15,27,28] The growth of bone and soft tissue surrounding the upper airway[13,27] and regression of the lymphoid tissue[10] among adolescents probably mask the changes in the pharynx by the incisors' retraction. A greater rate of changes in the soft-tissue measurements of the posterior pharyngeal wall occurs between 6 and 9 years and between 12 and 15 years.[29] Thus, all the subjects above 18 years were included in the present study to ensure that the oropharyngeal structures had reached the adult size and the effect from growth would not affect the result. Also, many previous studies reported no effect of incisors retraction on the sagittal dimensions of PAP in adult subjects with Class I bimaxillary dentoalveolar protrusion malocclusions.[1,15,25,28] Zhang et al.[14] observed that extraction orthodontic treatment in adults leads to widening of the upper airway in the lateral or transverse dimension to maintain its patency in the sagittal dimension. But, Sun et al.[30] noticed that first premolar extraction treatment could change the shape of oropharyngeal airway passage only to some extent. However, 3D CBCT evaluation of upper airway revealed that orthodontic treatment with premolar extraction did not affect sagittal and transverse dimensions, minimal cross-sectional area, and volume in the nasopharyngeal, retropalatal, or retroglossal regions of the upper airway in adult patients.[15] Thus, the surrounding soft tissues might have some adaptive changes for maintaining the upper airway dimensions after incisors retraction among adult subjects. Marşan et al.[31] observed that a more backward position of the tongue following large incisor retraction probably influences the soft palate and posterior pharyngeal walls to have adaptive changes. Previously, Zhang et al.[14] have also observed that the effect of extraction treatment on the upper airway seems to be an adaptive change in the airway morphology, rather than a decrease in the airway size.

The current study revealed that there are no changes in the soft palate dimensions in non-extraction subjects. But the length and thickness of the soft palate were increased and decreased, respectively, following retraction of incisors. The retraction of incisors might push the tongue backward and compressed the soft palate, thus resulting in a decrease in its thickness and an increase in its length. Further, no effect of non-extraction orthodontic treatment on the PPWT was observed, whereas it decreased significantly following incisor retractions among Class I bimaxillary malocclusions subjects. This could be an adaptive change in the posterior pharyngeal wall to maintain the sufficient patency of the upper airway. The loss of fat from the posterior pharyngeal wall might result in the reduction in its thickness. It was observed that the reduction of the PPWT was maximum at retropalatal and retroglossal regions compared to other regions. Such an adaptive change in the posterior pharyngeal wall may be a risk factor for the future development of sleep-disordered breathing, particularly when an individual becomes obese. The excess deposition of fat in the pharyngeal wall during adulthood can lead to constriction of the upper airway passage leading to the development of sleep-disordered breathing.

A systematic review reveals that bicuspid extraction and incisor retraction leads to narrowing of the upper airway in Asian adults and late adolescents.[26] Although the present study did not find any significant narrowing of the upper airway, it revealed that significant adaptations of the soft tissues surrounding the upper airway take place following bicuspid extraction and incisor retraction in Class I bimaxillary dentoalveolar protrusion malocclusion subjects. Also, this was a retrospective cross-sectional study based on lateral cephalograms, which cannot tell about the patient's subjective symptoms related to the breathing, casualty of orthodontic treatment, and 3D airway changes. However, the significance of this is to present clues of the PPWT changes following the retraction of the incisors during comprehensive orthodontic treatment. The present study included only female subjects, thus further investigations on males are needed to confirm the above conclusions and also longitudinal evaluations are needed to identify the long-term changes in the posterior pharyngeal wall following large retraction of the incisors.

The retraction of the incisors can be a risk factor for the future development of sleep-disordered breathing. Thus, before deciding about premolars extraction and large retraction of incisors, patients sleeping and breathing, and the family tendency for sleep-disordered breathing may be evaluated.

CONCLUSION

The following conclusions were drawn from the present study:

- The retraction of incisors in Class I bimaxillary dentoalveolar protrusion malocclusion subjects did not affect the sagittal dimensions of the pharyngeal airway passage.
- The thickness of the soft palate and posterior pharyngeal wall reduced as an adaptive change following the retraction of the incisors in Class I bimaxillary dentoalveolar protrusion malocclusion subjects.
- The adaptive change in the posterior pharyngeal wall was mainly at the retropalatal and retroglossal regions compared to other regions.

Ethics Committee Approval: This study was approved by the Institute Ethics Committee, All India Institute of Medical Sciences, Bhubaneswar (T/IM-NF/Dentistry/20/151) and was conducted according to the principles of the Helsinki Declaration.

Informed Consent: Written informed consent was obtained from each patient for the comprehensive orthodontic treatment and to use their records for various academic and research activities.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.K.J.; Design - A.K.J., J.S.; Supervision - A.K.J.; Materials - A.K.J.; Data Collection and/or Processing - A.K.J., A.V., J.S.; Analysis and/or Interpretation - A.K.J., J.S.; Literature Review - A.V., J.S.; Writing - A.K.J., A.V., J.S.; Critical Review - A.K.J., J.S.

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REFERENCES

1. Al Maaitah E, El Said N, Abu Alhaija ES. First premolar extraction effects on upper airway dimension in bimaxillary proclination patients. *Angle Orthod*. 2012;82(5):853-859. [CrossRef]
2. Bandy HE, Hunter WS. Tongue volume and the mandibular dentition. *Am J Orthod*. 1969;56(2):134-142. [CrossRef]
3. Lowe AA, Gionhaku N, Takeuchi K, Fleetham JA. Three-dimensional CT reconstructions of tongue and airway in adult subjects with obstructive sleep apnea. *Am J Orthod Dentofacial Orthop*. 1986;90(5):364-374. [CrossRef]
4. Germec-Cakan D, Taner T, Akan S. Uvulo-glossopharyngeal dimensions in non-extraction, extraction with minimum anchorage, and extraction with maximum anchorage. *Eur J Orthod*. 2011;33(5):515-520. [CrossRef]
5. Chen Y, Hong L, Wang CL, et al. Effect of large incisor retraction on upper airway morphology in adult bimaxillary protrusion patients. *Angle Orthod*. 2012;82(6):964-970. [CrossRef]
6. Wang Q, Jia P, Anderson NK, Wang L, Lin J. Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary protrusion. *Angle Orthod*. 2012;82(1):115-121. [CrossRef]
7. Sharma K, Shrivastav S, Sharma N, Hotwani K, Murrell MD. Effects of first premolar extraction on airway dimensions in young adolescents: a retrospective cephalometric appraisal. *Contemp Clin Dent*. 2014;5(2):190-194. [CrossRef]
8. Nuvusetty B, Peddu R, Prakash AS, Kalyani M, Devikanth L, Chadalawada D. Assessment of changes in pharyngeal airway size and hyoid bone position following orthodontic treatment of Class I bimaxillary dentoalveolar protrusion. *J Indian Orthod Soc*. 2016;50:215-221.
9. Bhatia S, Jayan B, Chopra SS. Effect of retraction of anterior teeth on pharyngeal airway and hyoid bone position in Class I bimaxillary dentoalveolar protrusion. *Med J Armed Forces India*. 2016;72(Suppl 1):S17-S23. [CrossRef]
10. Nagmode S, Yadav P, Jadhav M. Effect of first premolar extraction on point A, point B, and pharyngeal airway dimension in patients with bimaxillary protrusion. *J Indian Orthod Soc*. 2017;51:239-244.
11. Maurya MRK, Kumar CP, Sharma LCM, Nehra LCK, Singh H, Chaudhari PK. Cephalometric appraisal of the effects of orthodontic treatment on total airway dimensions in adolescents. *J Oral Biol Craniofac Res*. 2019;9(1):51-56. [CrossRef]
12. Zheng Z, Liu H, Xu Q, et al. Computational fluid dynamics simulation of the upper airway response to large incisor retraction in adult Class I bimaxillary protrusion patients. *Sci Rep*. 2017:7:45706.
13. Valiathan M, El H, Hans MG, Palomo MJ. Effects of extraction versus non-extraction treatment on oropharyngeal airway volume. *Angle Orthod*. 2010;80(6):1068-1074. [CrossRef]
14. Zhang J, Chen G, Li W, Xu T, Gao X. Upper airway changes after orthodontic extraction treatment in adults: a preliminary study using cone beam computed tomography. *PLoS ONE*. 2015;10(11):e0143233. [CrossRef]
15. Joy A, Park J, Chambers DW, Oh H. Airway and cephalometric changes in adult orthodontic patients after premolar extractions. *Angle Orthod*. 2020;90(1):39-46. [CrossRef]
16. Cho HN, Yoon HJ, Park JH, Park YG, Kim SJ. Effect of extraction treatment on upper airway dimensions in patients with bimaxillary skeletal protrusion relative to their vertical skeletal pattern. *Korean J Orthod*. 2021;51(3):166-178. [CrossRef]
17. Jena AK, Singh SP, Utreja AK. Effectiveness of twin-block and mandibular protraction appliance-IV in the improvement of pharyngeal airway passage dimensions in Class II malocclusion subjects with a retrognathic mandible. *Angle Orthod*. 2013;83(4):728-734. [CrossRef]
18. Ghodke S, Utreja AK, Singh SP, Jena AK. Effects of twin-block appliance on the anatomy of pharyngeal airway passage (PAP) in Class II malocclusion subjects. *Prog Orthod*. 2014;15:68. [CrossRef]
19. Joseph AA, Elbaum J, Cisneros GJ, Eisig SB. A cephalometric comparative study of the soft tissue airway dimensions in persons with hyperdivergent and normodivergent facial patterns. *J Oral Maxillofac Surg*. 1998;56(2):135-139. [CrossRef]
20. Miles PG, O'Reilly M, Close J. The reliability of upper airway landmark identification. *Aust Orthod J*. 1995;14(1):3-6.
21. Miles PG, Vig PS, Weyant RJ, Forrest TD, Rockette Jr HE. Craniofacial structures and obstructive sleep apnea syndrome-a qualitative analysis and meta-analysis of the literature. *Am J Orthod Dentofacial Orthop*. 1996;109(2):163-172. [CrossRef]
22. 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]
23. Behrents RG, Shelgikar AV, Conley RS, et al. Obstructive sleep apnea and orthodontics: an American Association of Orthodontists White Paper. *Am J Orthod Dentofacial Orthop*. 2019;156(1):13-28.e1. [CrossRef]
24. Hu Z, Yin X, Liao J, Zhou C, Yang Z, Zou S. The effect of teeth extraction for orthodontic treatment on the upper airway: a systematic review. *Sleep Breath*. 2015;19(2):441-451. [CrossRef]
25. Aldosari MA, Alqasir AM, Alqahtani ND, Almosa NA, Almoammar KA, Albarakati SF. Evaluation of the airway space changes after extraction of four second premolars and orthodontic space closure in adult female patients with bimaxillary protrusion - a retrospective study. *Saudi Dent J*. 2020;32(3):142-147. [CrossRef]
26. Ng JH, Song YL, Yap AUJ. Effects of bicuspid extractions and incisor retraction on upper airway of Asian adults and late adolescents: a systematic review. *J Oral Rehabil*. 2019;46(11):1071-1087. [CrossRef]
27. Stefanovic N, El H, Chenin DL, Glisic B, Palomo JM. Three-dimensional pharyngeal airway changes in orthodontic patients treated with and without extractions. *Orthod Craniofac Res*. 2013;16(2):87-96. [CrossRef]
28. Pliska BT, Tam IT, Lowe AA, Madson AM, Almeida FR. Effect of orthodontic treatment on the upper airway volume in adults. *Am J Orthod Dentofacial Orthop*. 2016;150(6):937-944. [CrossRef]
29. 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]
30. Sun JW, Tang R, Gao J, Li YM. Three-dimensional changes of oropharyngeal airway after orthodontic extraction treatment in skeletal Class I adolescents. *Zhonghua Kou Qiang Yi Xue Za Zhi*. 2021;56(3):256-262. [CrossRef]
31. Marşan G, Vasfi Kuvat S, Oztaş E, Cura N, Süsal Z, Emekli U. Oropharyngeal airway changes following bimaxillary surgery in Class III female adults. *J Craniomaxillofac Surg*. 2009;37(2):69-73. [CrossRef]