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Original Article

Effect of retraction of anterior teeth on pharyngeal airway and hyoid bone position in Class I bimaxillary dentoalveolar protrusion

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ABSTRACT

Background: To test the hypothesis that the retraction of anterior teeth has no effect on the dimensions of pharyngeal airway and to evaluate the retraction of anterior teeth on each parameter of pharyngeal airway.

Methods: Twenty-two adult patients of Class I bimaxillary protrusion requiring first premolar extractions with maximum anchorage requirements were selected. The pharyngeal airway and dentofacial parameters of the patients were compared using pre- and post-treatment lateral cephalograms with the help of Student's paired t-test ($P < 0.05$). The relationship between airway size and dentofacial parameters was also evaluated using Pearson correlation coefficient.

Results: The upper and lower lips were retracted by 2.25 and 5.4 mm after retraction of the incisors. The tips of upper and lower incisors were retracted by 7.75 and 7.15 mm, respectively. There was a statistically significant decrease in SPP-SPPW ($P < 0.05$), U-MPW ($P < 0.001$), TB-TPPW ($P < 0.001$), and change in HRGN ($P < 0.01$). A significant correlation was observed between the amount of retraction of lower incisor and decrease in the pharyngeal airway posterior to soft palate ($r = 0.102$), tongue ($r = 0.322$), and change in HRGN ($r = 0.265$).

Conclusions: The size of the pharyngeal (velopharyngeal and glossopharyngeal) airway reduced and hyoid bone position changed after retraction of the incisors in extraction space in bimaxillary protrusive adult patients.

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Introduction

Bimaxillary dentoalveolar protrusion is a malocclusion characterized by proclined incisors with convex facial profile and lip incompetence. The cephalometric findings usually show an increased horizontal distance from the most protrusive point of upper lip to esthetic line, horizontal distance from the most protrusive point of lower lip – esthetic line, angle between the Frankfort horizontal plane and long axis of upper incisor, and angle between the mandibular plane and long axis of lower incisor.¹ Orthodontic treatment usually indicates extraction of four first premolars followed by retraction of anterior teeth in the extraction space.²

Studies^{1–8} have been carried out in the past to evaluate the relationship between pharyngeal airway and skeletal, dental parameters, soft tissue matrix including musculature, and growth patterns. It has been seen in the past that tongue position changed in the oral environment after mandibular setback by sagittal split ramus osteotomy.⁴ Significant correlation was observed between maxillary protrusion in skeletal Class III children and increase in the nasopharyngeal airway.⁵ Rapid maxillary expansion improved the nasopharyngeal airway and nasal width.⁶ The correlation between craniofacial growth pattern and pharyngeal airway was found to be doubtful.^{7,8}

Limited evidence-based research^{9,10} is available on the correlation of the retraction of anterior teeth in bimaxillary protrusion patients undergoing extraction of four premolars and the pharyngeal airway. A recent study⁹ showed that the orthodontic treatment with extraction of four premolars did influence oropharyngeal airway space in adults. Another study¹⁰ showed that the same orthodontic treatment did not influence oropharyngeal airway in adolescents. This finding has been supported due to pharyngeal growth in adolescents, but specific changes at all levels of pharyngeal airway and hyoid bone were not considered. A study by Germec-Cakan et al.¹¹ reported a significant decrease of pharyngeal airway posterior to the tip of soft palate and tongue after retraction of anteriors. Only velopharyngeal and glossopharyngeal airway space was calculated. Other parameters like nasopharynx, hypopharynx, and airway length were not evaluated. It is a well-documented fact that significant changes in dentofacial parameters are expected during extraction orthodontic treatment, which changes soft tissue profile and incisor angulation. These changes are likely to influence tongue position and pharyngeal airway.¹⁰ Literature about this aspect is still not sufficient, and therefore it is necessary to investigate the effect of retraction of anterior teeth on pharyngeal airway.

The aim of this retrospective study was to evaluate the effect of maximum retraction of anterior teeth at each level of pharyngeal airway and hyoid bone position after extraction of four first premolars in bimaxillary protrusion adults.

Materials and method

Records of around 150 patients were searched in the institution but only 22 patients (09 males and 13 females)

fulfilled our inclusion criteria. Therefore, the study was carried out on a selected patient sample only.

Inclusion criteria:

- Minimum age 17 years.
- Skeletal Class I, Class I molar, and canine relation.
- Well-aligned arches with no or minimal crowding.
- Protrusive lips and proclined anterior teeth with their value greater than 02 standard deviation above the normal mean value.
- Indication of therapeutic extraction of four first premolars.
- Indication of retraction of anterior teeth as a standard care of treatment.
- Group A anchorage.
- Maximum intercuspation of teeth.
- Good quality cephalograms.

Exclusion criteria:

- History of previous orthodontic/orthopedic treatment.
- History of cleft lip/palate, mouth breathing, permanent snoring, and tonsillectomy/adenoidectomy.
- Enlargement of tonsils or adenoids on lateral cephalogram.
- Teeth not in occlusion.

The mean preoperative age was 22.52 years with an overall range of 17–29 years. All patients underwent Roth 018 preadjusted edgewise appliance treatment with maximum anchorage reinforcement. There were only two types of anchorage reinforcements that were considered in this study.

- (a). Nance button with vertical pull headgear – 19 cases.
- (b). Transpalatal arch (TPA) with vertical pull headgear – 03 cases.

In these cases, second molars were also banded, and first and second molars were made as one unit bilaterally.

Vertical pull headgear was used for 14–16 h a day. Since it is not feasible for the patient to wear headgear for 24 h, additional anchorage in the form of TPA with banded second molars/Nance button was given to prevent anchorage loss during that time. Though some anchorage loss is still bound to happen, it will be minimal.

All pre- and post-treatment lateral cephalograms were standardized (same machine – Dimax-3, Planmeca Proline XC, same operator, linear magnification of 11%, and taken in end expiration).

The pharyngeal airway and hyoid bone were evaluated. The pharynx was divided into four levels – nasopharynx, velopharynx, glossopharynx, and hypopharynx. The cephalometric landmarks and analyses (Table 1, Fig. 1) for pharyngeal and hyoid bone were based on the methods described by Lowe et al.,¹² Liu et al.,¹³ and Zhong et al.¹⁴ The pre- and post-cephalograms for all the patients were traced on the acetate tracing paper by the same investigator. To check reproducibility error, the radiographs were again traced by the same investigator after 02 and 04 months. The mean differences were less than 1 mm and 1°. The standard error for each cephalometric value was calculated. Student's paired t-test¹⁵ was used to determine systematic error and P value, for these

Table 1 – Cephalometric landmarks and measurements.

Landmarks	Definition
Hor	Most inferior point of spheno-occipital synchondrosis
R	Point of intersection of line from Hor to PNS and posterior pharyngeal wall
Ba	Lowermost point on anterior margin of foramen magnum
Ad1	Point of intersection of posterior pharyngeal wall and line Ptm-Ba
SPPW	Point of intersection of line from soft palate center perpendicular to posterior pharyngeal wall
SPP	Point of intersection of line from soft palate center perpendicular to posterior pharyngeal wall and posterior margin of soft palate
U	The tip of the uvula
MPW	Foot point of perpendicular line from point U to posterior pharyngeal wall
TPPW	Point of intersection of posterior pharyngeal wall and extension of line B-Go
TB	Point of intersection of base of tongue and extension of line B-Go
V	The most posteroinferior point on base of tongue
LPW	Foot point of perpendicular line from point V to posterior pharyngeal wall
E	Base of epiglottis
C3	The most anteroinferior point of the third vertebra
H	The most superior and anterior point of hyoid bone
RGN	The most protrusive point of retrognathion
H1	Foot point of perpendicular line from RGN to C3
Upper airway, mm	
PNS-R	Distance between PNS and R
PNS-Ad1	Distance between PNS and Ad1
SPP-SPPW	Distance between SPP and SPPW
U-MPW	Distance between U and MPW
TB-TPPW	Distance between TB and TPPW
V-LPW	Distance between V and LPW
VAL	Vertical airway length and distance between PNS and V
Hyoid position	
HRGN, mm	Distance between H and RGN
HH1, mm	Distance between H and H1
C3H, mm	Distance between C3 and H
SH, mm	Distance between S and H
Dentofacial measurements	
ANB, °	Angle between point A and B at nasion
FH/MP, °	Angle between mandibular plane and the FH plane
U1/FH, °	Angle between FH plane and long axis of upper incisors
L1/MP, °	Angle between mandibular plane and long axis of lower incisors
UL-E line, mm	Horizontal distance from most protrusive point of upper lip to E line
LL-E line, mm	Horizontal distance from the most protrusive point of lower lip to E line
U1FHp, mm	Horizontal distance from the tip of the upper incisor crown to constructed FH plane vertical
L1FHp, mm	Horizontal distance from the tip of the lower incisor crown to constructed FH plane vertical
U6FHp, mm	Horizontal distance from the distal point of the upper first molar crown to constructed FH plane vertical
L6FHp, mm	Horizontal distance from the distal point of the lower first molar crown to constructed FH plane vertical

differences were not found to be significant. Pearson correlation coefficient showed a statistically significant range for the reliability of observations.

Statistical analysis

'Matlab 1' software package was used for statistical analysis. A normally distributed population was observed for pre- and postoperative values (Shapiro–Wilk test). A Student's paired sample t-test was used for comparing pre- and post-treatment measurements. A Pearson linear correlation analysis was performed for evaluating association between pharyngeal airway and dentofacial parameters.

Results

Demographic data showed no difference between male and female patients.¹⁶ A recent study¹⁷ has shown that there is no effect of growth pattern on pharyngeal airway.

Following maximum retraction of the incisors (Table 2), the upper and lower lips were retracted by 2.2 mm ($P < 0.0001$) and 5.4 mm ($P < 0.0001$), respectively. The mean decrease in the U1/FH angle was 11° ($P < 0.0001$), and for L1/MP, it was 11.9° ($P < 0.0001$). The tip of the upper incisor was retracted by 7.75 mm ($P < 0.0001$) and the tip of the lower incisor was retracted by 7.15 mm ($P < 0.0001$). However, the

Fig. 1 – Cephalometric landmarks and analyses of pharyngeal airway and dentofacial parameters.

ANB angle, the mandibular plane angle (FH/MP), U6FHp in mm, and L6FHp in mm did not show any significant changes ($P > 0.05$).

The results (Table 2) showed a statistically significant decrease in SPP-SPPW ($P < 0.05$), U-MPW ($P < 0.0001$), TB-TPPW ($P < 0.0001$), and HRGN ($P < 0.01$) whereas changes in V-LPW, VAL, C3H, SH, PNS-R, PNS-Ad1, and HH1 showed no significant differences ($P > 0.05$). Velopharynx and glossopharynx were reduced significantly post-treatment with the hyoid bone

moving in a posterior direction. The correlation (Table 3, Fig. 3) between the retraction distance of the lower incisor and the airway behind the soft palate (SPP-SPPW), the tongue (TB-TPPW), and change in HRGN was found to be significant.

The mean percentage reduction of pharyngeal airway size was found to be – SPP-SPPW (16.72%), TB-TPPW (19.56%), and U-MPW (22.27%). The mean percentage posterior movement of hyoid bone after retraction of lower incisor was found to be 11.64%.

Table 2 – Changes in pharyngeal airway, hyoid bone, and dentofacial parameters ($n = 22$) (comparison of pretreatment and post-treatment cephalometric values).

Variable	Pre		Post		Pre-post		P value
	Mean	SD	Mean	SD	Mean	SD	
Upper airway							
PNS-R	20.4	2.12	20.25	2.18	0.15	0.38	0.193
PNS-Ad1	29.4	6.54	28.5	6.19	0.9	1.68	0.149
SPP-SPPW	15.55	3.09	12.95	1.79	2.6	2.77	0.016
U-MPW	12.8	3.04	9.95	2.89	2.85	1.84	0.000**
TB-TPPW	13.55	3.19	10.8	3.39	2.65	1.47	0.000**
V-LPW	11.05	3.44	11	4.01	−0.05	1.04	0.892
VAL	55.05	3.58	55.1	2.93	−0.05	1.59	0.922
Hyoid position							
HRGN	39.95	5.49	35.3	7.32	4.65	3.79	0.004*
HH1	5.3	2.83	4.2	3.46	0.5	1.9	0.057
C3H	31.7	2.74	30.85	2.96	1.45	1.5	0.2
SH	93.5	3.66	93.5	4.17	0	3.33	1
Dentofacial parameters							
ANB	6.2	1.6	5.7	1.7	0.5	1.25	0.236
FH/MP	29.5	5.56	30.3	4.4	−0.8	1.75	0.182
U1/FH	117.7	9.31	104.65	6.38	11	4.52	0.000**
L1/MP	102.2	5.35	90.3	4.32	11.9	6.72	0.000**
UL-E line	1.45	1.42	−0.8	1.49	2.25	0.95	0.000**
LL-E line	6.15	1.8	0.75	2.51	5.4	2.17	0.000**
U1FHp, mm	75.2	4.5	67.45	3.88	7.75	3.39	0.000**
L1FHp, mm	72	4.58	65.25	2.49	7.15	3.4	0.000**
U6FHp, mm	33.85	4.18	33.8	3.59	0.05	1.01	0.879
L6FHp, mm	34.2	4.23	34.05	3.4	0.25	1.75	0.794

* $P < 0.01$.

** $P < 0.0001$.

Table 3 – Linear correlation analysis between pharyngeal airway size and hyoid bone with dentofacial parameters (r = Pearson correlation coefficient).

	SPP-SPPW	U-MPW	TB-TPPW	HRGN	HH1
Variable	r	r	r	r	r
Δ L1FHp	0.102	–0.023	0.322	0.265	–0.133

Discussion

In our study, the pharyngeal airway reduced after maximal retraction of anterior teeth in Class I bimaxillary protrusion patients (Fig. 2) with extraction of four first premolars, similar to the findings by Wang et al.⁹ and Germec-Cakan et al.¹¹ According to Wang et al.,⁹ there is a significant decrease in SPP-SPPW, U-MPW, TB-TPPW, V-LPW, VAL, C3H, and SH and no significant changes in PNS-R, PNS-Ad1, HRGN, and HH1; but in our study, the only differences from the above mentioned study were significant changes in HRGN and no significant decrease in V-LPW, VAL, C3H, and SH. This confirms that maximal retraction of the anterior teeth did influence the pharyngeal airway posterior to the level of soft palate, uvula, and tongue in adults. The hyoid bone in the present study moved posteriorly similar to the finding by Wang et al.⁹; however, it did not move inferiorly. According to Wang et al.,⁹ hyoid bone moved both posteriorly and inferiorly.

In the present study, there were significant changes in the velopharynx and glossopharynx but no changes were observed in the nasopharynx and hypopharynx due to the fact that the nasopharynx and hypopharynx are not easy to deform because of supportive bone and cartilage, while the antetheca of the velopharynx and glossopharynx is made up of the soft palate and tongue, which were easily affected by the change in the surrounding tissue. Retraction of incisors after extraction with maximum anchorage decreased the oral space → tongue pressing on the soft palate → adaptation leading to the decrease in the size of the upper airway.¹⁰

Fig. 2 – Superimposition of a pretreatment and post-treatment lateral cephalogram.

According to a recent study by Valiathan et al.,¹⁰ pharyngeal airway did not change significantly after retraction of anterior teeth with extraction of four premolars in adolescents. The authors supported their negative finding to mandibular growth. In their study,¹⁰ anchorage reinforcement system was not specified, while in our study, TPA/Nance button with headgears was applied for Group A type of anchorage similar to the study by Wang et al.⁹ who had used mini-implants/headgear, which may be the reason for the different results. In the study by Wang et al., they have not specified the distribution of patients wearing headgear/mini-implants. Moreover, they have not specified whether they have used Nance button/TPA/banding second molars along with the type of headgear. Anchorage loss during nonwearing of headgear in a day has not been specified (bias/confounding factor) in their study. The mean reduction of pharyngeal airway size reduction at various levels was SPP-SPPW by 16.72%, U-MPW by 22.27%, and TB-TPPW by 19.56%. In our study, mean decrease of pharyngeal airway (SPP-SPPW-2.6 mm, U-MPW-2.85 mm, and TB-TPPW-2.65 mm) was more as compared to the study by Wang et al.⁹ (SPP-SPPW-0.56 mm, U-MPW-0.85 mm, and TB-TPPW-1.63 mm) probably due to minimum anchorage loss and better retraction of upper and lower incisors in our study. In the present study, the upper and lower incisors were retracted by 7.75 mm and 7.15 mm, respectively as compared to Wang et al.⁹ study in which upper and lower incisors were retracted by 6.84 mm and 4.95 mm, respectively. This also implies that the reduction in the pharyngeal airway (velopharyngeal and glossopharyngeal) is dependent on the amount of retraction distance of incisors.

The HRGN value (% age posterior movement of hyoid bone) was 11.64%. Though the value of HH1 (inferior movement of hyoid bone) was not found to be statistically significant, the mean % age inferior movement of hyoid bone was 9.4%. This showed that the hyoid bone did move posteriorly by 4.65 mm (mean) and inferiorly by 0.5 mm (mean) after maximal retraction of anterior teeth. Though the inferior movement was not statistically significant, it may be significant clinically. Similar results were found in a recent study by Wang et al.⁹ in which both posterior and inferior movements of hyoid bone after maximal retraction of anterior teeth were found to be statistically significant. The position of the hyoid bone changes with the movement of the tongue in the pharyngeal airway. The hyoid bone moves posteriorly and inferiorly during retraction of the anterior teeth in order to prevent the shifting of the tongue into the pharyngeal airway.

In order to maintain the homogeneity of the sample, the anchorage reinforcement was maintained. Moreover, all the patients were above 17 years of age, and the confounding factor of growth potential interfering with our results is ruled out similar to the study by Wang et al.⁹ Dental parameters exhibited significant changes after orthodontic treatment as compared to skeletal parameters. Therefore, it is shown that

Fig. 3 – A column chart showing correlation of pharyngeal airway, hyoid bone, and mean retraction distance of lower incisor (x-axis = mean retraction distance of lower incisor and y-axis = r -coefficient of linear correlation).

there is a significant relationship between movement of anterior teeth and the size of the pharyngeal airway and movement of hyoid bone in adults (Fig. 2).

In our study, the relation between amount of incisor retraction and reduction in airway size was evaluated. The changes occurred mainly in the sagittal direction. This implies that there was a reduction of anterior boundary of the oral cavity and its contents, and mainly tongue has to shift posteriorly.¹⁸ The tongue adaptation is likely to reduce the velopharyngeal and glossopharyngeal airway and this explains the relation of movement of anterior teeth and reduction of pharyngeal airway at the level of soft palate and tongue in adults. That is why there is significant relationship between movement of lower incisors and reduction in velopharynx and glossopharynx. Change in the lower incisor positioning may affect the positioning of hyoid bone.^{9,19} According to Wang et al.,⁹ the lower incisors retracted by 4.95 mm and hyoid bone moved posteriorly and inferiorly (both were statistically significant) as compared to our study in which lower incisors retracted by 7.15 mm and the hyoid bone did move posteriorly by 4.65 mm (mean, statistically significant) and inferiorly by 0.5 mm (mean, statistically not significant). In other words, the amount of retraction of lower incisors is directly proportional to the reduction in pharyngeal airway size.

Many studies^{5,7,14,20,21} have proved the reliability of lateral cephalograms in evaluating pharyngeal airway, and therefore use of cephalograms in this study is justified. Lateral cephalograms only give a linear dimension of the airway; airway being a three-dimensional soft tissue structure, it needs to be evaluated in its three dimensions, especially when evaluating its different parts as they behave independently; hence, a recent focus of the specialty is by a three-dimensional evaluation; 3D CBCT studies are proving the same differently and would definitely replace lateral cephalograms in the future. Using lateral cephalograms is a limitation of the study. Lateral cephalogram is a standard diagnostic aid that is taken for all patients undergoing orthodontic treatment. Prescribing 3D CBCT for these patients will expose them to unnecessary radiation exposure and may not be justified for patients.

Clinical relevance of the study

The reduced pharyngeal airway dimensions and its impact on breathing during sleep merits consideration. We have to

consider the impact of orthodontic extractions on tongue space. Tongue posture and oral space are key variables to be considered for fixed orthodontic treatment with bicuspid extractions. Dr William Hang, one of the strongest advocates of bioblock orthotropics, has recommended optimizing oral posture as the core philosophy of dentofacial orthopedics.^{22,23} He has attributed bicuspid extractions for orthodontic treatment as the cause in some cases of obstructive sleep apnea (OSA). The reopening of extraction spaces in these cases had helped resolve OSA.²³ Good esthetics should never be achieved for patients undergoing orthodontic treatment at the expense of diminishing capacity of the upper airway.²⁴ A case of OSA may worsen following bicuspid extractions. Therefore, there is a need for a proactive research to correlate the impact of bicuspid extractions for orthodontic treatment on airway and merits consideration especially in a long-term study. Moreover, there is a need to foresee these types of patients and treatment plan should be modified depending on the risk-benefit ratio for orthodontic extractions. It is also recommended to document the prognosis in these cases during diagnosis and treatment planning involving orthodontic extractions. Anterior boundary of the oral cavity reduced in both mandibular setback and maximum retraction of anterior teeth after premolar extractions resulting in reduced pharyngeal airway; therefore, there is a similarity between these two types of treatment. The treatment modality in setback and retraction of teeth may be different but the impact on decrease in oral volume for tongue is similar. The pharyngeal airway in mandibular setback is reduced immediately, while during retraction of incisors, it is reduced over a period of time. During retraction of anterior teeth, pharyngeal airway reduced only at the soft tissue level (tongue and soft palate) and they are highly correlated with incisor movement. There was minimal correlation between pharyngeal airway at hard tissue level and retraction of anterior teeth. There was no effect of retraction of anterior teeth on vertical airway length. That implies that the effect was observed more in horizontal dimensions rather than in vertical dimensions of pharyngeal airway.

Future recommendations of this study will be to assess the pharyngeal airway size, tongue adaptation, and hyoid bone positioning on the long-term basis after more than 2–3 years post-treatment, since in the long-term study⁴ after mandibular setback, the pharyngeal airway showed a tendency to return to its original dimensions. Although tongue (size and

position) (pre- and post-treatment) is a vital structure that may have effect on the pharyngeal airway as explained in this study, still further studies are recommended on this aspect as one of the studies by Al Maaitah et al.²⁵ found no correlation between them.

Conclusion

- The pharyngeal airway dimensions reduced after retraction of anterior teeth especially at two levels – velopharynx and glossopharynx.
- The hyoid bone tends to move in the posterior direction.
- A significant correlation was observed between retraction of lower incisors and reduction of pharyngeal airway dimensions.
- Consideration should be made on the impact of bicuspid extractions with maximum incisor retraction on the tongue space and the pharyngeal airway as it may lead to narrowing of the airway. The treatment plan may be modified depending on the risk-benefit ratio for the patient.

Conflicts of interest

The authors have none to declare.

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