Original Articles

Effects of Orthodontic Treatment on the Upper Airway Dimension in Non-growing Patients

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Abstract

The upper airway dimension can be affected by many factors including orthodontic treatment. Previous studies showed large anterior teeth retraction decreased the length and volume of the upper airway. However, no studies have presented the effects of the amount of anterior teeth retraction on the upper airway. This study aimed to evaluate the effects of the amount of anterior retraction on the upper airway and hyoid position. The extraction group included 107 adult patients diagnosed with skeletal Class I relationship and dental Class I malocclusion who received four premolar extractions. Thirty adult patients who received non-extraction treatment were selected for the non-extraction group. The extraction group was divided into three subgroups depending on the retraction distance of lower incisors: E1 for small amounts, E2 for medium amounts, and E3 for large amounts of lower incisors retraction. Lateral cephalograms before and after treatment were collected. Comparisons of the three extraction subgroups showed differences between groups at SPP-SPPW, TB-TPPW and V-LPW. At the level of the soft palate (SPP-SPPW), E1 was different from E2. At the level of the base of the tongue (TB-TBBW), E1 was different from E3. At the level of the epiglottis (V-LPW), E1 was different from E2 and E3 ($P<0.05$). In summary, the retraction of lower incisors of more than 3 mm might decrease velopharynx, glossopharynx and hypopharynx.

Keywords: Cephalogram, Orthodontics, Skeletal pattern, Upper airway

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Introduction

The goals of orthodontic treatment are to provide harmonization and stability of occlusion, facial esthetics and function of related muscles including the respiratory function. The upper airway plays an important role in the growth and development of the craniofacial and dentofacial complex. It cooperates with surrounding structures to perform the physiological processes of vocalization, the digestive system and the respiratory system.[1]

One of the problems related to the respiratory function is Obstructive Sleep Apnea (OSA), which is a sleep disorder associated with arterial oxygen desaturation, sleep disruption, severe snoring, and excessive daytime sleepiness. This has increasingly affected the younger population and consequently results in chronic neuropsychiatric and cardiovascular sequelae.[2]

From the literature review, some orthodontic treatment modalities may increase the risk of OSA. Conventional orthodontic treatment with premolar extraction followed by large distances of incisor retraction significantly decreased the airway dimension.[3-5] However, some studies documented no difference in airway dimensional changes with less incisors retraction amounts.[6,7] There have been very few studies comparing the effect of the amount of incisors retraction distance on the upper airway dimension.

The aims of this retrospective study were to compare the airway dimensional changes between groups with different amounts of incisors retraction in adults with four premolars extracted for orthodontic treatment.

Materials and methods

A purposive sampling method was used to select 107 patients who received orthodontic treatment in the Orthodontic Clinic, Dental Hospital, Prince of Songkla University from 521 patients who had undergone conventional orthodontic treatment combined with four premolar extractions (Extraction group or E group) according to the following inclusion criteria:

1. Adults (aged 17 to 35 years old)
2. No medical problems or history of chronic infection of the respiratory system
3. No craniofacial anomalies
4. No previous orthodontic treatment or orthognathic surgery
5. Having a skeletal Class I relationship and dental Class I malocclusion
6. Treated with a fixed adjusted edgewise appliance and having four premolars extracted with subsequent anterior teeth retraction
7. No missing teeth (except third molars)
8. Pre- and post-treatment data, and cephalometric radiographs of adequate diagnostic quality

The extraction group was divided into three subgroups:

The E1 group had small amounts of lower incisors retraction 0-3 mm. (n=31)

The E2 group had a medium amount of lower incisors retraction >3-6 mm. (n=45)

The E3 group had a large amount of lower incisors retraction >6 mm. (n=31)

Compared with the control group, 30 patients who underwent conventional orthodontic treatment without premolar extraction were selected as the non-extraction group (NE). The extraction subgroups and the non-extraction group were compared by the amount of incisor retraction and changes in diameter of the upper airway dimension.

Statistical analysis

All data was analyzed by the Statistical Package for Social Sciences (SPSS version 17, SPSS Inc., Chicago, IL, USA) at the significance level of 0.05. Descriptive statistics were performed to analyze demographic data. Pre- and post-treatment variables of the non-extraction and extraction group were compared by the Wilcoxon test. The Kruskal-Wallis 1-way ANOVA test was performed

to compare upper airway dimensional changes between extraction subgroups and the non-extraction group.

Cephalometric analysis

Two lateral cephalometric radiographs for each patient were obtained before and after treatment with the patient standing with a natural head position. All the films were analyzed by Dolphin Imaging 11.9®. Magnification of radiographs were corrected. The cephalometric landmarks and airway analysis were modified based on the methods described previously by Lowe *et al*[8], Chen *et al*[9] and Wang *et al*[5]. (Fig. 1, 2 and Table 1)

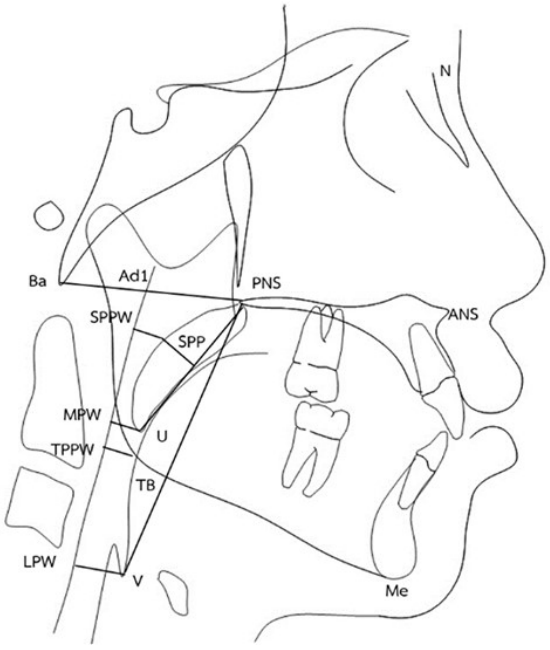

Figure 1 *The cephalometric landmarks and analyses of the upper pharyngeal airway*

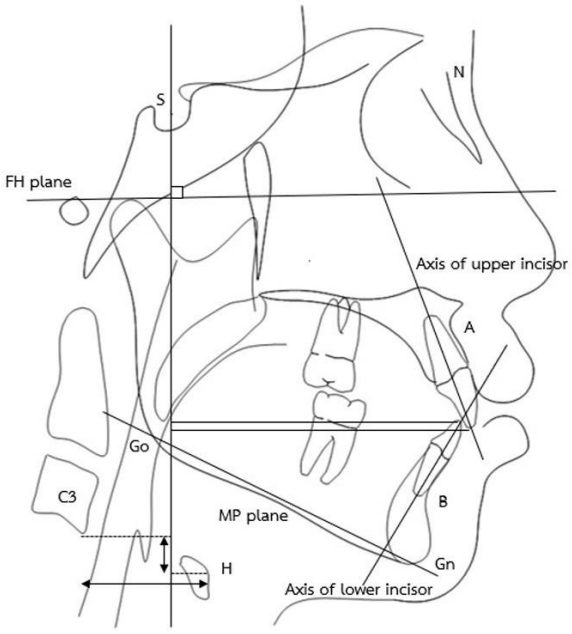

Figure 2 *The cephalometric landmarks and analyses of the dentofacial complex and hyoid bone*

Table 1 *Cephalometric Landmarks and Measurements*

Variables	Definition
Landmarks	
Ba	Lowermost point on anterior margin of foramen magnum
Ad1	Point of intersection of posterior pharyngeal wall and line PNS-Ba
SPPW	Point of perpendicular line from posterior margin of soft palate to posterior pharyngeal wall
SPP	Point of perpendicular line from soft palate center to posterior margin of soft palate
U	The tip of the uvula
MPW	Point of perpendicular line from point U to posterior pharyngeal wall
TPPW	Point of perpendicular line from posterior pharyngeal wall and TB
TB	Point of intersection of base of the tongue and posterior mandible
V	The most posteroinferior point on the base of the tongue
LPW	Point of perpendicular line from point V to posterior pharyngeal wall
C3	The most anteroinferior point of the third vertebra
H	The most anterosuperior point of hyoid bone
Upper airway, mm	
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, distance between PNS and V
Hyoid position, mm	
C3H on FHp	Distance between C3 and H parallel to FH plane
C3H on FHperp	Distance between C3 and H perpendicular to FH plane
SH on FHp	Distance between S and H parallel to FH plane
SH on FHperp	Distance between S and H perpendicular to FH plane
Dentofacial measurements	
SNA, degrees	Angle between sella and point A at nasion
SNB, degrees	Angle between sella and point B at nasion
ANB, degrees	Angle between point A and B at nasion
FH/MP, degrees	Mandibular plane angle: FH-GoGn
U1/FH, degrees	Angle between the FH plane and long axis of upper incisors
L1/MP, degrees	Angle between the mandibular plane and long axis of lower incisors
U1-Svert, mm	Distance from upper incisor crown tip to constructed S vertical line perpendicular to FH plane (Svert)
L1-Svert, mm	Distance from lower incisor crown tip to Svert

Results

Dahlberg's errors for a random radiograph were 0.32- 0.45 mm for all variables and the range of intraclass correlation was calculated as 0.94-0.98, presenting a high similarity of remeasurement.

The extraction group consisteded of 26 males and 81 females, with a mean age before treatment of 22.9 ± 4.67 years old. The extraction group was classified into E1, E2 and E3 subgroups and had 31, 45 and 31 samples, respectively. The non-extraction group had 11 males and 19 females with a mean age before treatment of 21.94 ± 4.18 years old. There was no significant difference in the sexes between the groups. (Table 2)

Table 2 *Demographic data*

Group	NE	E1	E2	E3	Total E
Male (n)	11	5	9	8	26
Female (n)	19	26	36	23	81
Total (n)	30	31	45	31	107
Age (year)	21.94 ± 4.18	21.19 ± 3.86	22.51 ± 5.02	24.27 ± 4.57	22.90 ±4.67

The comparison of pre-treatment parameters between groups was shown in Table 3. The comparison of pre- and post-treatment parameters of the extraction and non-extraction group was shown in Table 4. In the non-extraction group, dentofacial parameters showed a significant decrease in the SNB angle, an increase in the ANB angle, a retroclination of upper incisors (decreased U1/FH angle), and a proclination of the lower incisors (increased L1/MP angle). The upper airway dimension showed a significant increase in U-MPW, TB-TPPW and V-LPW distance.

Table 3 *Pre-treatment parameters of the Non-extraction group and 4 Extraction subgroups*

Parameter	NE (n=30)	E1 (n=31)	E2 (n=45)	E3 (n=31)	*P* values
SNA, degrees	84.60 ± 4.28	84.00 ± 5.20	84.20 ± 6.25	83.70 ± 3.80	0.493
SNB, degrees	80.90 ± 5.49	80.70 ± 5.60	80.70 ± 6.50	79.70 ± 3.60	0.107
ANB, degrees	3.45 ± 2.99	2.00 ± 2.80	3.10 ± 1.80	4.50 ± 2.20	0.723
FH/MP, degrees	28.30 ± 7.8	25.50 ± 5.80	25.70 ± 3.47	27.00 ± 6.60	0.056
U1/FH, degrees	121.40 ± 7.10	122.80 ± 8.80	125.00 ± 10.95	122.00 ± 10.30	0.055
L1/MP, degrees	99.05 ± 8.97	99.70 ± 5.20	104.00 ± 10.85	105.10 ± 6.70	0.007*
U1-Svert, mm	71.95 ± 6.68	75.60 ± 6.10	77.00 ± 8.05	74.10 ± 6.00	0.002*
L1-Svert, mm	68.70 ± 6.13	70.20 ± 5.90	73.60 ± 7.99	71.50 ± 6.80	0.005*
Upper airway, mm.					
PNS-Ad1	25.05 ± 3.55	25.00 ± 4.00	25.60 ± 4.10	25.00 ± 5.20	0.777
SPP-SPPW	11.40 ± 4.30	13.20 ± 4.30	12.50 ± 3.05	13.20 ± 2.60	0.341
U-MPW	9.27 ± 3.27	9.90 ± 5.30	10.30 ± 5.60	9.70 ± 3.60	0.442
TB-TPPW	9.95 ± 2.19	9.30 ± 3.90	10.40 ± 3.85	9.40 ± 3.50	0.669
V-LPW	14.10 ± 3.70	14.50 ± 3.10	15.70 ± 4.69	15.20 ± 3.80	0.215
VAL	58.56 ± 13.15	58.90 ± 6.10	61.40 ± 11.15	58.80 ± 6.90	0.553
Hyoid position, mm.					
C3H on FHp	5.80 ± 1.83	8.20 ± 7.30	4.40 ± 5.93	6.40 ± 6.00	0.790
C3H on FHperp	32.40 ± 5.12	31.00 ± 6.60	32.10 ± 6.00	31.60 ± 4.50	0.907
SH on FHp	95.85 ± 12.30	98.10 ± 11.30	97.90 ± 14.45	96.70 ± 9.30	0.266
SH on FHperp	13.90 ± 4.41	17.80 ± 9.10	16.70 ± 11.50	16.90 ± 8.90	0.025*

Table 4 *Pre- and post-treatment parameters of the Non-extraction and Extraction group*

Parameter	*Non-extraction group*				*Extraction group*			
	Pre (Med ± IQR)	Post (Med ± IQR)	Post-Pre (Med ± IQR)	*P-* values	Pre (Med ± IQR)	Post (Med ± IQR)	Post-Pre (Med ± IQR)	*P-values*
SNA, degrees	84.60 ± 4.28	84.00 ± 3.80	0.10 ± 0.70	0.202	84.00 ± 5.50	83.90 ± 5.40	0.00 ± 0.60	0.104
SNB, degrees	80.90 ± 5.49	80.10 ± 6.30	-0.50 ± 1.30	0.003*	80.10 ± 5.90	80.20 ± 5.60	0.00 ± 0.60	0.892
ANB, degrees	3.45 ± 2.99	3.76 ± 2.70	0.40 ± 1.26	0.000*	3.10 ± 2.70	3.10 ± 3.20	-0.10 ± 0.70	0.327
FH/MP, degrees	28.30 ± 7.80	27.40 ± 8.17	0.00 ± 1.49	0.909	26.40 ± 4.00	26.40 ±4.00	0.20 ± 1.00	0.083
U1/FH, degrees	121.40 ± 7.10	115.7 ± 6.25	-3.35 ± 8.82	0.000*	123.70 ± 8.80	110.80 ± 10.50	-12.70 ± 6.60	0.000*
L1/MP, degrees	99.05 ± 8.97	100.95 ±7.05	1.80 ± 5.15	0.003*	103.20 ± 8.80	95.3 ± 9.10	-7.80 ± 8.50	0.000*
U1-Svert, mm	71.95 ± 6.68	71.40 ± 6.14	0.60 ± 1.96	0.599	75.60 ± 6.40	69.40 ± 6.50	-6.00 ± 2.80	0.000*
L1-Svert, mm	68.70 ± 6.13	69.20 ± 5.27	1.20 ± 2.88	0.060	71.90 ± 7.30	67.00 ± 6.40	-5.00 ± 3.30	0.000*
Upper airway, mm.								
PNS-Ad1	25.05 ± 3.55	26.40 ± 4.5	0.35 ± 2.61	0.059	25.40 ± 4.20	25.30 ± 4.30	-0.20 ± 1.70	0.472
SPP-SPPW	11.40 ± 4.30	12.05 ± 4.15	0.35 ± 1.45	0.106	12.90 ± 3.50	11.20 ± 4.30	-0.90 ± 1.90	0.000*
U-MPW	9.27 ± 3.27	9.78 ± 5.50	0.70 ± 1.63	0.006*	10.00 ± 4.70	7.80 ± 4.20	-1.50 ± 2.00	0.000*
TB-TPPW	9.95 ± 2.19	10.35 ± 5.10	0.37 ± 2.8	0.029*	10.00 ± 3.00	8.50 ± 3.90	-1.40 ± 2.80	0.000*
V-LPW	14.10 ± 3.70	14.80 ± 4.10	0.40 ± 1.76	0.004*	15.20 ± 3.50	14.80 ± 3.10	-0.60 ± 1.40	0.000*
VAL	58.56 ± 13.15	58.25 ± 10.10	0.3 ± 2.25	0.213	59.00 ± 8.30	59.60 ± 7.00	0.30 ± 2.50	0.419
Hyoid position, mm.								
C3H on FHp	5.80 ± 1.83	6.23 ± 3.27	0.40 ± 2.12	0.829	6.10 ± 6.40	5.30 ± 6.60	0.10 ± 2.40	0.103
C3H on FHperp	32.40 ± 5.12	30.50 ± 5.15	0.45 ± 2.60	0.544	31.70 ± 5.60	31.00 ± 5.20	-0.70 ± 3.40	0.593
SH on FHp	95.85 ± 12.30	97.00 ± 11.60	0.075 ± 4.96	0.072	96.70 ± 9.30	97.90 ± 10.80	0.70 ± 4.10	0.049*
SH on FHperp	13.90 ± 4.41	15.50 ± 5.76	0.95 ± 3.8	0.599	17.60 ± 9.20	17.90 ± 8.40	-0.50 ± 4.30	0.176

In the extraction group, dentofacial parameters showed significant retroclined upper and lower incisors (decreased at the U1-FH and L1-MP angle) and retracted upper and lower incisors (decreased U1-Svert and L1-Svert distances). The upper airway dimension showed significantly decreased SPP-SPPW, U-MPW, TB-TPPW, and V-LPW distance. Also, the hyoid bone position was repositioned inferiorly (increased SH on FHp).

The comparison of airway dimensional changes between three extraction subgroups (Table 5) showed that there were differences between the groups at the levels of SPP-SPPW, TB-TPPW and V-LPW. In Figure 3, there was a significant difference when comparing the lower incisors retraction amount and the upper airway dimensional change between the three extraction subgroups. At the soft palate level (SPP-SPPW), the small retraction subgroup (E1) was significantly different from the medium retraction subgroup (E2). At the base of the tongue level (TB-TBBW), the small retraction subgroup (E1) was significantly different from the large retraction subgroup (E3). At the epiglottis level (V-LPW), the small retraction subgroup (E1) was significantly different from the medium and large retraction subgroup (E2 and E3).

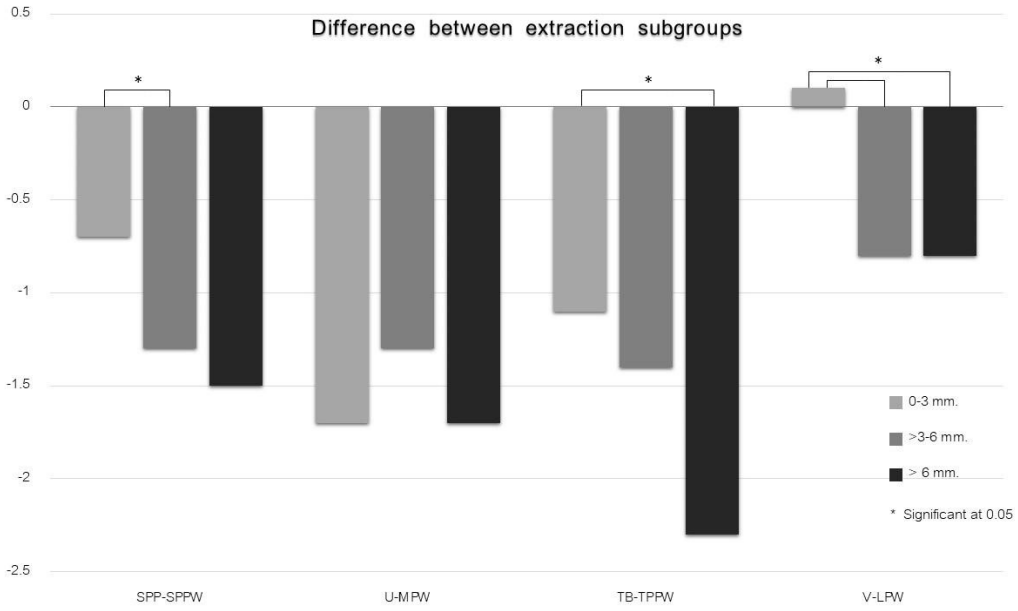

Figure 3 *Comparison of lower incisors retraction amount and upper airway dimensional change between the 3 extraction subgroups*

Table 5 *Comparison of lower incisors retraction amount and upper airway dimensional change between 3 extraction subgroups*

LIS RETRACTION AMOUNT	0-3 MM. (N=31)	>3-6 MM. (N=53)	> 6 MM. (N=31)	sig
PNS-UPW	-0.5 ± 1.80	-0.03± 1.60	-0.1± 2.40	0.996
SPP-SPPW	-0.7 ±1.0	-1.3 ± 2.35	-1.5 ±2.70	0.018*
U-MPW	-1.7 ± 1.8	-1.30± 2.35	-1.70 ±1.90	0.333
TB-TPPW	-1.1 ± 1.9	-1.4 ± 3.25	-2.30 ±1.20	0.000*
V-LPW	0.1 ±2.30	-0.8 ±1.25	-0.8 ±1.40	0.006*

Discussion

The samples of this study included healthy adults with no chronic respiratory disease or sleep disorder for the reason of controlling the upper airway structure with normal function and physiology of the airway. All of them were diagnosed with having a skeletal Class I relationship and dental Class I malocclusion to control the contributing factor of a craniofacial pattern that related with the size of the upper airway.[10,11]

Cephalometric analysis of the upper airway in this study was performed by two dimensional radiographs at a static natural head position of the samples, which was the conventional data for orthodontic patient evaluation without the complicated implements. Malkoc *et al.*[12] suggested that two-dimensional measurement of an airway dimension from the lateral cephalogram can be reliable and reproduced. However, it cannot investigate dynamic function and airway volume like a 3-dimensional image. Nevertheless, Aboudara *et al.*[13] compared a three-dimensional cone beam computed tomography (CBCT) and a conventional cephalometric radiograph, where they found a significant positive relationship between the upper airway size in width and volume.

The objectives of most studies were to compare the results after orthodontic treatment between the non-extraction and extraction group in a skeletal and dental Class I relationship.[3,5] There have been very few studies focusing on any changes of incisors positions and how they affect the upper airway. So, this study focused on comparing the amount of change of retraction in extraction cases to the upper airway dimensions.

In this study, the non-extraction group had significantly changed the SNB and ANB angle, which was contrary to the study of German-Cakan *et al.*[4] where there were no significant different skeletal and dental variables after treatment in a treated control group because a non-extraction group with air-rotor stripping was studied, but in this study in the non-extraction group, one of the treatment modalities was dental arch expansion. Therefore, there was relative extrusion of the posterior teeth that affected mandibular clockwise rotation and relative retrusion.[14] However, the number of those changes was negligible (SNB -0.50 ± 1.30 and ANB 0.40 ± 1.26) and the FMA was not significantly changed.

As in previous studies, either in cephalometric analysis or CBCT analysis, conventional orthodontic treatment with four premolar extractions with maximum anchorage and large incisors retraction, the velopharynx, glossopharynx and hypopharynx decreased significantly.[3,5] Despite that, some studies showed no significant changes in the airway dimension, but the anchorage situation was not identified and the amount of incisors retraction in their study was less than in others.[6,7] These findings showed the average amount of upper incisors retraction was -6.00 ± 2.80 mm. and the lower incisors retraction was -5.00 ± 3.30 mm. It was found that the upper airway dimension significantly decreased at the velopharynx, glossopharynx and hypopharynx level in the extraction group. The glossopharynx decreased the most by 15 %, which agreed with the study of Wang *et al.*[5] where they found that the glossopharynx (TB-TPPW) was reduced by 33.3 %, and the velopharynx and hypopharynx (SPP-SPPW, U-MPW and V-LPW) was reduced by about 10-20 %. Chen *et al.*[3] found decreased cross-sectional areas of the hypopharynx (38.19 %) being more than the glossopharynx and palatopharynx (20-25 %). In contrast to the non-extraction group, the upper airway significantly increased, which corresponded with lower incisors proclination and protrusion.

The hyoid bone, commonly called the tongue-bone, is an attachment of the tongue through multiple muscular and connective tissue. Movement of the tongue posteriorly and inferiorly considering anterior teeth retraction results in a narrowing of the airway. Wang *et al.* and Chen *et al.*[3,5] stated that hyoid position changes were observed moving more in a posterior and inferior direction. Nevertheless, Maaitah *et al.*[6] and our findings showed no significant changes except the SH on the FHp distance, which presented an inferior

movement of hyoid bone. Disagreement was likely due to the difficulty of precise measurements of the hyoid position by a cephalogram because there were slight variations in head position, spine position, and the state of neuromuscular function.[15]

This study is the first comparison of the amount of incisors retraction distance that could affect airway dimensional changes. In extraction cases of conventional orthodontic treatment, the anchorage situation was classified into three types relying on the amount of posterior teeth movement to where the space closure was designed. "Maximum anchorage" means a situation which requires no or little anchorage being lost, whereas "moderate anchorage" means half a space was closed by the anchorage movement, and "minimum anchorage" means that the extraction space was almost closed by the anchorage segment.[16] Thus the amount of anterior teeth retraction was divided into three groups depending on a one-third estimation of the premolar extraction space.

The results showed a significant difference between extraction subgroups at the velopharynx, glossopharynx and hypopharynx levels, and the small retraction subgroup had less changes when compared with the other two groups. These results could imply that for extraction cases that retract lower incisors by more than 3 mm or in orthodontic treatment combined with extraction of four premolars, moderate to maximum anchorage would impact the airway dimension. So, the patients who had a narrow airway dimension or who had a history of sleep disorder should be treated with caution.

Conclusion

In conventional orthodontic treatment, four premolars extraction with retraction of lower incisors of more than 3 mm might decrease the velopharynx, glossopharynx and hypopharynx. The most affected area was the glossopharynx.

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