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Evaluation of airway dimensions and changes in hyoid bone position following class II functional therapy with activator

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Abstract

Aim. The aim of this study was to evaluate the long-term effects of Class 2 functional treatment on airway dimensions and positional changes in hyoid bone and compare it with that of an untreated Class 2 control group. ***Methods.*** Lateral cephalograms of 16 patients (eight girls, eight boys, mean chronological age = 11.36 ± 0.77 years) who were treated with activator and 19 patients (11 girls, eight boys, mean chronological age = 12.14 ± 0.65 years) who served as control were used for linear, angular and area measurements regarding airway track and hyoid bone. ***Statistics.*** Intra-group comparisons were performed by paired *t*-test and Wilcoxon test, whereas independent *t*-test and Mann Whitney-U were used for inter-group comparisons. ***Results.*** During treatment (T2–T1), nasopharyngeal height and nasopharyngeal area increased ($p < 0.05$) and hyoid bone moved downward (H-SN; $p < 0.001$) and forward (H-C3; $p < 0.01$). During retention period (T3–T2); nasopharyngeal ($p < 0.01$) and oropharyngeal area increased ($p < 0.05$). H-SN ($p < 0.01$) and C3-H distances ($p < 0.05$) increased. Hyoid bone position exhibited significant changes (H-SN, $p < 0.001$; C3-H, $p < 0.01$). The increases in C3-H in long-term was more in the activator group than control ($p < 0.05$). ***Conclusions.*** In growing Class 2 patients with mandibular deficiency and airway track without obstructions, functional appliance treatment provided favorable effects on nasopharyngeal and oropharyngeal area throughout the retention period.

Key Words: *airway, skeletal Class 2, functional therapy, hyoid bone*

Introduction

Certain epigenetic factors such as establishing and maintaining the airway passage can alter the relationship between head, jaws, dentition and the tongue [1]. This suggests a connection between respiratory track and development of orthodontic problems. Previously, the link between respiratory function and development of malocclusion has been considered as an effect of the 'soft-tissue pressures' which could possibly effect the growth direction of the jaws and respiratory mode [2]. Several studies were made concerning the relation between the pharyngeal and craniofacial structures [3–5] and reported results particularly touched on the association between airway problems, Class 2 skeletal discrepancies and vertical growth [2,4,6].

Skeletal Class 2 discrepancy with mandibular deficiency is considered as a risk factor for upper airway disorders and oropharyngeal airway deficiencies [6–9]. In order to prevent the potential respiratory problems, Li [10] noticed that early orthodontic treatment of mandibular deficiencies in skeletal class II patients would be beneficial. Numerous types of functional appliances for correction of Class 2 relationship innovate sagittal mandibular growth during adolescence [11]. These appliances are also used to prevent apneas or airway problems by forcing the mandible, hyoid bone, tongue and soft palate forward, thus causing an increase in oropharyngeal dimensions [12,13].

Analysis of airway track can be made by certain methods, among which lateral cephalometry is an accepted and commonly used technique for diagnosis

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[7] and evaluation of treatment results concerning obstructive sleep apnea [14]. Despite some limitations [9,15], it was reported that measurements on lateral cephalograms concerning airway dimensions were highly accurate [16]. In fact, some authors proposed that lateral cephalometry is a simple and reproducible method for assessment of the airway [17,18].

There are few studies evaluating the effects of Class 2 functional orthopedic treatment on airway dimensions [12,13,19–21]. Yet, the outcome obtained from these studies are limited as; (1) the changes were reported just after the active treatment phase [12,13], (2) linear measurements were used to examine the difference in nasopharyngeal and oropharyngeal airways [20,21] and (3) similarly growing control subjects were not always present [13,21]. Therefore, the aim of this study was to evaluate the long-term effects of Class 2 functional treatment with activator on the airway morphology and position of hyoid bone and compare it with that of an untreated Class 2 control group. The hypothesis was that airway dimensions of children presenting skeletal class 2 patterns due to mandibular retrognathia would increase with activator treatment and this effect would continue after the retention period.

Materials and methods

This retrospective study consisted of lateral cephalograms of skeletal Class 2 subjects with mandibular retrognathia which were selected from the archives of Gazi University Department of Orthodontics. The main inclusion criteria were as follows:

(1) Skeletal (ANB >5°) and dental Class II malocclusion with retrognathic mandible (SNB <80°),
(2) Increased overjet (>5 mm) with no functional shift or dual bite,
(3) Optimal mandibular plane angle (SN/GoGn: 32 ± 6°),
(4) No congenital anomalies,
(5) No medical history about a respiratory problem or an upper airway surgery,
(6) Presence of good quality lateral cephalograms taken at natural head position (NHP) and hand and wrist radiographs at the beginning and at the end of treatment and observation periods,
(7) Written informed consent forms, medical and dental records present, and
(8) Treated only with activator, no combination with expansion, servical or occipital headgear.

From patients who fulfilled the above criteria, patients who were at pre-pubertal growth period [22] were enrolled in the study. Sample size was calculated with a statistical power of 0.80 and the number of patients per group was required to be a minimum of 12.

The activator group (16 patients; eight girls, eight boys, mean chronological age: 11.36 ± 0.77 years) were treated only with activator that was constructed with 5–7 mm sagittal and 4–5 mm vertical activation for an average of 11 ± 3.4 months. The patients were instructed to use the appliance for 16–18 hours per day and active treatment was ended when a Class I molar relationship and ideal overjet (2–3 mm) were achieved. After active treatment phase patients were enrolled in a retention phase with a mean follow up time of 29.75 ± 5.17 months. Retentions were performed by night-time wearing of the appliances.

The data of the untreated control group consisted of 19 patients demonstrating skeletal Class 2 pattern (11 girls, eight boys, mean chronological age = 12.14 ± 0.65 years), who needed fixed appliance therapy and observed until proper oral hygiene was achieved, were matched with treatment groups according to their chronological age. The mean observation period was 11.37 ± 1.2 months without any treatment.

Lateral cephalometric radiographs of all subjects were taken in natural head position (NHP) with Trophy Instrumentarium Cephalometer (OP 100, Instrumentarium Imaging Co, Tuusula, Finland) at 70 kVp and 16 mA/s; under standard conditions after a usual swallow and in centric occlusion. Lateral cephalograms were manually traced on acetate papers by the same researcher at the beginning (T1), end of active treatment phase (T2) and retention phase (T3) for the activator group; and at the beginning (O1) and end of the observation period (O2) for the control group. The measurements were corrected for the standard magnification. Linear and angular measurements performed on the tracings are given in Figure 1. For the area measurements, the palatal line through ANS-PNS, the sphenoid line tangent to lower border of the sphenoid registered on basion (Ba) and the pterygomaxillary line perpendicular to the palate line registered on pterygomaxillare were traced. The upper airway area was divided into two regions by the palatal line; the nasopharyngeal area (NA) and oropharyngeal area (OA). The palatal line and the base of the epiglottis were accepted as the upper and lower borders of OA (Figure 2). The area measurements were performed by NETCAD for Windows, 5.1.0.962, Software (Ulusal Co., Ankara, Turkey). This is an engineering drawing software used for topographic studies. The cephalometric radiographs were scanned (EPSON Perfection, V700 Photo, Japan) at standard conditions. The NA and OA were digitized according to the specified points by two different researchers to obtain maximum reliability and agreement. The numerical value of the areas was calculated by the software and the derived numbers were designated as units.

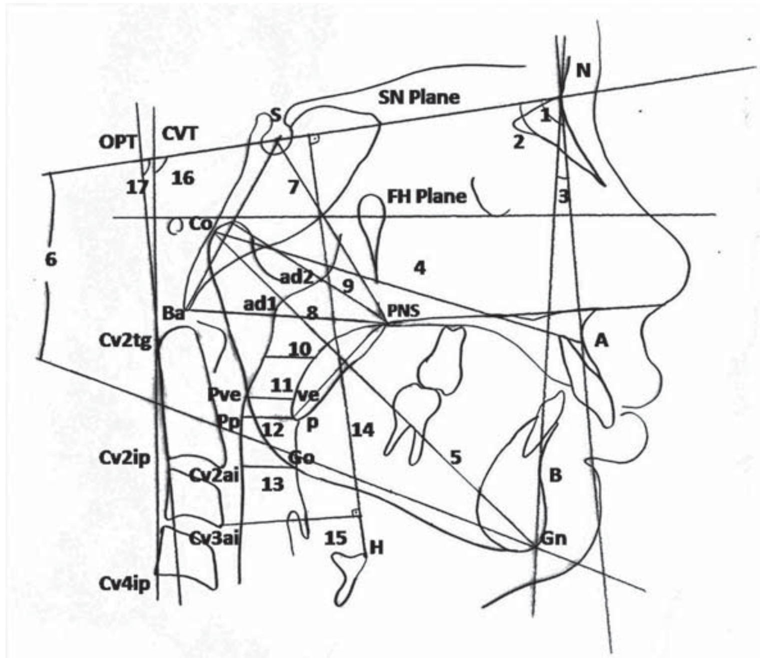

Figure 1. Cephalometric points, planes and measurements used in this study. (1) SNA, the angle measuring the anteroposterior relationship of the maxillary basal arch on the anterior cranial base; (2) SNB, the angle showing the anterior limit of the mandibular basal arch in relation to the anterior cranial base; (3) ANB, the angle for skeletal orthodontic classification; (4) Co-A, effective maxillary length; (5) Co-Gn, effective maxillary length; (6) SN-GoGn, the angle measuring the inclination of the mandibular plane in relation to the anterior base of the cranium; (7) S-PNS, nasopharyngeal height between points S and PNS; (8) ad1-PNS, the distance from PNS to the adenoid tissue along the line from PNS to the pharyngeal wall along the line from Ba to PNS; (9) ad2-PNS, the distance from PNS to the adenoid tissue along the line from PNS to the mid-point of the line intersecting Ba to S; (10) SPS, the distance of the midpoint of the line from PNS to tip of soft palate (P) to the horizontal counterpart on the posterior pharyngeal wall along a parallel line to the Frankfurt horizontal plane; (11) ve-Pve, the distance of velum palatinum to the horizontal counterpart on the posterior pharyngeal wall along a parallel line to the Frankfurt horizontal plane; (12) MPS, the distance of the tip of the soft palate to the horizontal counterpart on the posterior pharyngeal wall along a parallel line to the Frankfurt horizontal plane; (13) IPS, the distance of the intersection points on anterior and posterior pharyngeal wall through Cv2ai along a parallel line to the Frankfurt horizontal plane; (14) H-SN, the perpendicular distance from hyoid bone to SN plane; (15) C3-H, the distance from the anterio-inferior point of the third cervical vertebra to point H; (16) SN-CVT, the downward angle between the SN plane and the line through Cv2tg and Cv4ip; (17) SN-OPT, the downward angle between the SN plane and the line through Cv2tg and Cv2ip.

Statistical analysis

To evaluate the error in tracings, 15 radiographs were randomly selected, re-traced and re-measured by the same researcher after 15 days. Intra-class correlation coefficient was found to be within acceptable limits (0.94–0.97). Data were analyzed using SPSS software for Windows, version 15.0 (SPSS Inc., Chicago, IL). Intra-group comparisons were performed by paired *t*-test and Wilcoxon test. Inter-group differences were calculated with independent *t*-test and Mann Whitney-U tests. In order to evaluate the relationship between changes in pharyngeal airway and craniofacial morphology, Spearman correlation analysis was performed. The statistical significance level was established as $p < 0.05$.

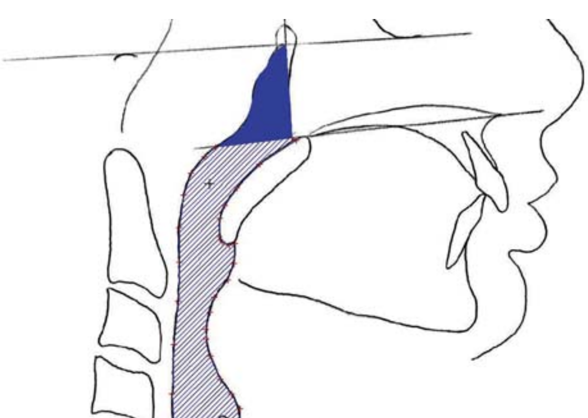

Figure 2. Nasopharyngeal (NA, blue section) and oropharyngeal area (OA, striped section) measurements performed by NETCAD Software Programme.

Results

The homogenity of pre-treatment and pre-observation of the groups is shown in Table I.

Changes in control group (O2–O1)

A significant decrease in ANB angle was found at a significance level of $p < 0.05$ and increases in Co-A and Go-Gn distances were found ($p < 0.001$, respectively). Significant increases in nasopharyngeal height (S-PNS, $p < 0.001$) and nasopharyngeal airway

Table I. Homogeneity at pre-treatment and pre-observation (T1).

Variables	Control group Mean	SD	Activator group Mean	SD	p
Skeletal morphology					
SNA	81.42	2.61	80.78	3.59	0.540
SNB	76.05	2.52	74.65	3.69	0.190
ANB	5.36	1.16	6.12	1.90	0.160
CoA	89.63	4.65	88.12	3.44	0.360
CoGN	111.84	4.48	107.06	6.93	0.020*
SN/GoGn	31.68	5.62	31.50	4.47	0.800
Nasopharynx					
S-PNS	49.84	3.43	48.19	2.40	0.115
ad1-PNS	25.58	6.15	25.75	4.69	0.920
ad2-PNS	21.05	3.92	20.13	3.32	0.461
Nasopharyngeal area	4316.00	1056.00	4036.00	1142.00	0.460
Oropharynx					
SPS	13.42	2.56	13.90	2.99	0.609
ve-Pve	11.00	2.58	10.37	2.58	0.481
MPS	11.10	2.90	10.78	2.99	0.748
IPS	9.73	2.13	10.06	2.86	0.703
Oropharyngeal area	9873.00	1942.00	8968.00	2255.00	0.218
Hyoid bone					
H-SN	105.73	7.12	99.21	5.19	0.005**
H-C3	32.73	4.55	32.59	2.98	0.545
Head posture					
SN/CVT	105.53	6.19	105.56	9.11	0.989
SN/OPT	102.89	6.60	104.63	9.59	0.533

SD, Standard deviation, * $p < 0.05$; ** $p < 0.01$; NS, non-significant.

dimensions (ad2-PNS, $p < 0.01$) were found. Also, hyoid bone position exhibited significant changes (H-SN, $p < 0.001$; C3-H, $p < 0.01$) (Table II).

Changes in activator group (T2–T1)

Changes in skeletal morphology after treatment included significant decrease in ANB angle at a significance level of $p < 0.05$, while Co-Gn measurement demonstrated an increase ($p < 0.05$). Nasopharyngeal height and nasopharyngeal area measurements revealed significant increases (S-PNS, NA; $p < 0.05$, respectively). Hyoid bone position with respect to SN plane and C3 exhibited significant increases (H-SN, $p < 0.001$; C3-H, $p < 0.01$) (Table II).

Changes during retention period (T3–T2)

CoGn, nasopharyngeal area and oropharyngeal area increased significantly ($p < 0.05$, $p < 0.01$ and $p < 0.05$, respectively). H-SN and C3-H distances increased with a significance level of $p < 0.01$ and $p < 0.05$, respectively (Table II).

Total treatment changes (T3–T1)

Both SNB angle and CoGn distance declared a significant increase ($p < 0.05$ and $p < 0.01$, respectively), revealing a significant decrease in ANB angle at a significance level of $p < 0.001$. Both nasopharyngeal and oropharyngeal area measurements continue to increase significantly ($p < 0.001$ and $p < 0.01$, respectively). Hyoid bone position exhibited significant changes (H-SN, $p < 0.001$; C3-H, $p < 0.01$) (Table II).

Comparison of the changes between groups

Comparison of the differences between control and treatment periods is shown in Table III, declaring no significant difference. When changes in retention period were compared with the control period,

Table II. Descriptive statistics and comparison of variables at pre-treatment (T1), post-treatment (T2), post-retention (T3), pre-observation (O1) and post-observation (O2) periods.

	Control group					Activator group								
	Pre-observation (O1)		Pre-observation (O2)			Pre-treatment (T1)		Post-treatment (T2)		Post-treatment (T3)		*p*		
Measurements	Mean	SD	Mean	SD	p O2–O1	Mean	SD	Mean	SD	Mean	SD	T2–T1	T3–T2	T3–T1
Skeletal morphology														
SNA (°)	81.42	2.61	80.95	2.37	NS	80.78	3.59	80.68	4.19	80.09	3.99	NS	NS	NS
SNB (°)	76.05	2.52	76.05	1.95	NS	74.65	3.69	75.68	3.78	76.18	3.78	NS	NS	**
ANB (°)	5.37	1.16	4.89	1.44	*	6.12	1.90	5.00	2.00	3.90	2.30	*	NS	***
CoA (mm)	89.63	4.65	92.79	6.13	***	88.12	3.44	90.94	7.01	90.93	5.33	NS	NS	NS
CoGn (mm)	111.84	4.48	116.05	6.51	***	107.06	6.93	111.90	7.38	116.56	7.41	*	*	***
SNGoGn (°)	31.68	5.62	32.31	6.67	NS	31.50	4.47	32.00	4.59	31.25	4.93	NS	NS	NS
Nasopharynx S-PNS (mm)	49.84	3.43	51.52	4.26	***	48.19	2.40	49.15	2.44	49.81	2.68	*	NS	NS
ad1-PNS (mm)	25.58	6.15	26.63	5.90	NS	25.75	4.67	26.12	4.52	27.25	4.75	NS	NS	NS
ad2-PNS (mm)	21.05	3.92	22.68	3.90	**	20.13	3.32	21.00	4.60	21.90	3.07	NS	NS	NS
Nasopharyngeal area	4316	1056	4 714	1046	NS	4036	1142	4 594	1201	5 315	1133	*	**	***
Oropharynx														
SPS (mm)	13.42	2.56	13.42	2.34	NS	13.90	2.99	14.37	2.16	15.25	2.72	NS	NS	NS
ve-Pve (mm)	11.00	2.58	10.52	2.50	NS	10.37	2.58	10.15	2.27	11.56	2.85	NS	NS	NS
MPS (mm)	11.10	2.90	10.57	2.36	NS	10.78	2.99	10.21	2.20	11.44	3.03	NS	NS	NS
IPS (mm)	9.73	2.13	9.84	2.60	NS	10.06	2.86	9.71	2.45	11.68	3.78	NS	NS	NS
Oropharyngeal area	9873	1942	10 481	2613	NS	8968	2254	10 048	1650	11 165	1677	NS	*	**
Hyoid bone														
H-SN (mm)	105.73	7.12	111.11	7.25	***	99.21	5.19	102.88	5.45	107.63	6.57	**	**	***
C3-H (mm)	32.73	4.55	34.42	4.56	**	32.59	2.98	34.40	3.47	36.15	3.20	*	*	**
Head posture														
SNCVT (°)	105.53	6.19	106.26	6.42	NS	105.56	9.11	106.25	9.51	109.38	8.03	NS	NS	NS
SNOPT (°)	102.89	6.60	103.53	7.53	NS	104.63	9.59	104.94	9.82	106.50	8.32	NS	NS	NS

SD, Standard deviation, * $p <. 05$; ** $p < 0.01$; *** $p < 0.001$; NS, non-significant.

Table III. Comparison of the differences between the control and the treatment periods.

	Control group O2–O1		Activator group T2–T1		
	Mean	SD	Mean	SD	p
Skeletal morphology					
SNA (°)	−0.47	1.34	−0.09	1.40	NS
SNB (°)	0.00	1.33	1.03	2.14	NS
ANB (°)	−0.47	0.91	−1.13	1.64	NS
CoA (mm)	3.16	2.61	2.81	5.20	NS
CoGn (mm)	4.21	3.63	4.84	6.84	NS
SNGoGn (°)	0.63	2.67	0.50	2.70	NS
Nasopharynx					
S-PNS (mm)	1.68	1.60	0.97	1.19	NS
ad1-PNS (mm)	1.05	2.41	0.38	2.60	NS
ad2-PNS (mm)	1.63	1.83	0.87	2.52	NS
Nasopharyngeal area	398	841	558	763	NS
Oropharynx					
SPS (mm)	0.00	1.85	0.47	2.44	NS
ve-Pve (mm)	−0.47	3.25	−0.22	2.21	NS
MPS (mm)	−0.53	3.04	−0.56	1.84	NS
IPS (mm)	0.11	1.41	−0.34	3.83	NS
Oropharyngeal area	607	1766	1079	2257	NS
Hyoid bone					
H-SN (mm)	5.37	3.62	3.66	3.52	NS
C3-H (mm)	1.68	1.60	1.81	2.50	NS
Head posture					
SNCVT (°)	0.74	4.54	0.69	8.58	NS
SNOPT (°)	0.63	4.38	0.31	8.97	NS

O1, pre-observation; O2, post-observation; T1, pre-treatment; T2, post-treatment; SD, standard deviation; NS, non-significant.

more prominent changes were found in post-retention period (Table IV). Hyoid bone position with respect to C3 showed higher increase in activator group than in control group ($p < 0.05$).

Results of correlation analysis

The measurements related to the airway dimensions (Nasopharyngeal area, oropharyngeal area, ad1-PNS, ad2-PNS, MPS, SPS, IPS) were considered as dependent variables, whereas SNA, SNB, CoGn, SN/GoGn, SN/CVT, SN/OPT, H-SN and C3-H were selected as independent variables. For the control group, there were no significant correlations. However, for the treatment group, change in C3-H was positively correlated to the change in MPS ($r = 0.596$; $p = 0.015$).

Discussion

Functional orthopedic treatment in growing children is known to be an effective method to enhance sagittal mandibular growth and correct skeletal Class 2 problems due to retrognathic mandible. It was previously reported that these appliances can also alter airway dimensions positively and prohibit possible obstructions in the future [23]. Still studies have limitations due to the lack of control groups or reporting only short-term effects [13,19,20]. Retention is desirable in functional therapies until the end of adolescence and can be made by night-time wearing of the appliance either in the original way or cut down. This study was set up to evaluate the effects of activator treatment on the pharyngeal airway morphology on a long-term basis and compare it with an untreated control group. Our results showed that prominent skeletal changes were mainly occurred in the retention period with respect to the observation period. Although treatment group induced favorable changes in nasopharyngeal area, no significant difference was found when compared with the control group neither in short nor in the long-term. In relation to these, the hypothesis was rejected. Our findings were in contrast with previous studies [6,12,20]. This might be attributed to the fact that the patients in our

Table IV. Comparison of changes between the control and retention periods.

	Control group O2–O1		Activator group T3–T1		
	Mean	SD	Mean	SD	*p*
Skeletal morphology					
SNA (°)	−0.47	1.34	−0.68	1.34	NS
SNB (°)	0.00	1.33	1.53	1.32	**
ANB (°)	−0.47	0.91	−2.21	0.74	***
CoA (mm)	3.16	2.61	2.81	1.58	NS
CoGn (mm)	4.21	3.63	9.50	2.53	**
SNGoGn (○)	0.63	2.67	−0.25	1.66	NS
Nasopharynx					
S-PNS (mm)	1.68	1.60	1.62	0.90	NS
ad1-PNS (mm)	1.05	2.41	1.50	1.67	NS
ad2-PNS (mm)	1.63	1.83	1.78	1.13	NS
Nasopharyngeal area	398	841	1278	402	NS
Oropharynx					
SPS (mm)	0.00	1.85	1.34	1.01	NS
ve-Pve (mm)	−0.47	3.25	1.18	0.96	NS
MPS (mm)	−0.53	3.04	0.65	1.06	NS
IPS (mm)	0.11	1.41	1.62	1.18	NS
Oropharyngeal area	607	1766	2196	702	NS
Hyoid bone					
H-SN (mm)	5.37	3.62	8.40	2.09	NS
C3-H (mm)	1.68	1.60	3.56	1.09	*
Head posture					
SNCVT (°)	0.74	4.54	3.81	3.03	NS
SNOPT (°)	0.63	4.38	1.87	2.81	NS

O1, pre-observation; O2, post-observation; T1, pre-treatment; T2, post-retention, SD, standard deviation, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS, non-significant.

treatment group were at the beginning of pubertal growth at the beginning of activator treatment, therefore significant changes in the airway size related to the growth process were not expected. However, a combination of growth changes and the effects of functional appliance might be considered as favorable in nasopharyngeal and oropharyngeal area throughout the retention period. Additionally, cases with retrognathic facial structures and/or patients with sleep disorders due to relatively smaller pharyngeal dimensions would have demonstrated greater advancement of airway dimensions and reveal greater intrinsic stimulus to increase their capacity. However, subjects in our study already had adequate airway capacity and thus might not be in need of improvement in these structures.

The nasopharyngeal dimensions representing adenoid area on the posterior pharyngeal wall demonstrated significant increase in the control group. This result might be related with the physiological growth pattern of the lymphoid tissue. According to the knowledge that the mean size of the adenoids continue to grow until puberty with a gradual decline afterwards [24], the adenoid tissue was approximately after the peak of growing at the ages of the control subjects included in this study.

The position of hyoid bone is an indicator of tongue posture and function and several authors have analyzed the effects of orthodontic and orthognathic treatments on hyoid position and function [25,26]. In our study, hyoid bone moved in an inferior direction in both groups. As the hyoid bone moves posteriorly, there is a tendency for the tongue to encroach upon the pharyngeal airway. In order not to compromise the vital airway passage, the posteriorly displaced hyoid structures are guided to an inferior position [25]. Our results support Zhou's [27] study, who showed a downward displacement of the hyoid bone after functional treatment, but do not support a previous study which declared that hyoid bone moved upwards following functional mandibular advancement in the short-term; however, it moved downwards towards its original position in the long-term as a compensatory action [28]. Treatment with functional appliances provide hyper-activity of the geniohyoid, mylohyoid and the anterior component of the digastric muscles which are responsible for downward movement of the mandible. Therefore, the inferior positioning might depend on the balance between the suprahyoid and infrahyoid muscles.

Current measurements showed that hyoid bone tended to move anteriorly, which was more noticeable in the treatment group and were probably due to the more anterior displacement of the mandible, in line with the findings of Jena et al. [20]. As the genioglossus muscle is the main protruder of the tongue, it acts as an accessory respiratory muscle, resulting in advancement of the base of the tongue and dilation of the airway [29,30]. Zhou et al. [27] also found that hyoid moved forward and downward following treatment with FR-I. In accordance with the current results, Yassaei and Sorush [19] declared similar results. The anteroposterior position of the mandible most likely affects the position of the base of the tongue, because the tongue is connected to the inner surface of the anterior mandible by the genioglossus muscle. Correlation analysis showed a positive correlation between anteroposterior position of the hyoid bone relative to the third cervical vertebra and oropharyngeal airway measurement at the level of the soft palate. Forward positioning of the hyoid bone is an indicator of the effectiveness of the functional appliance. Therefore, it might be claimed that functional appliance treatment leads to forward reposition of the tongue.

The airway analysis for this research was performed on lateral cephalograms. Lateral cephalograms were said to be insufficient and leading to errors while analyzing a three-dimensional (3-D) anatomic structure within two dimensions [9,15]. However, some studies reported that measurements about nasopharyngeal, oropharyngeal and retropalatal regions in lateral cephalograms were highly correlated with 3-D measurements [17,18]. Yet, archives of two dimensional cephalograms are still very important for evaluation of treatment effects both in the short- and long-term as reliable, attainable and cheaper diagnostic tools.

Conclusions

(1) In growing Class 2 patients with mandibular deficiency without any airway obstructions, functional appliance treatment provided favorable effects on nasopharyngeal and oropharyngeal area throughout the retention period.
(2) The anteriorly forced position of the mandible with functional appliance treatment caused positional changes in hyoid bone due to possible enhanced muscle activities.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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