ASDJ
AINSHAMS DENTAL JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
September 2024 • Vol. 35

Comparative Analysis of Oropharyngeal Airway Changes: Xbow versus Forsus Appliances – A Retrospective Study

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Aim: This retrospective study aims to estimate the oropharyngeal airway space changes following treatment with the Xbow appliance and compare it with Forsus appliance.
Materials and Methods: This study involved pre- and post-treatment lateral cephalometrics of 63 adolescent patients with Class II mandibular retrognathism malocclusion, separated into three distinct groups; Group I: 21 patients (15 girls, 6 boys, mean age: 13±2.4) treated with Xbow, Group II: 21 patients (13 girls, 8 boys, mean age: 12±3.1) treated with Forsus, and Group III: 21 untreated class II patients (12 girls, 9 boys, mean age: 13±1.8) received no orthodontic treatment as control. Changes in lower and upper airway thickness, lower and upper adenoid thickness, lower and upper pharynx dimension were then analyzed.
Results: The airway dimensions improved significantly with Xbow and Forsus compared to the control group. Xbow significantly improved all parameters except the lower pharynx dimension, which showed no significant changes across the groups ($p = 0.357$). Forsus showed significant alteration in all parameters except the lower airway thickness ($p= 0.407$). Xbow significantly increase the lower and upper airway thickness compared to Forsus and control groups ($p < 0.001$).
Conclusion: Both Xbow and Forsus treatments yielded positive results in enhancing oropharyngeal airway dimensions in class II patients, with the Xbow treatment showing a more pronounced impact on both lower and upper airway thickness measurements.

Keywords: Class II malocclusion, Oropharyngeal airway, Xbow, Forsus

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Introduction

Skeletal Class II malocclusion is among the most prevalent dentoskeletal malformations with an estimated prevalence of around one-third of population.[1] This condition can arise from either mandibular retrognathism, maxillary prognathism, or both. Mandibular retrognathism is widely recognized as the most prevalent cause.[2-4] Therefore, the space between mandibular corpus and vertebral column reduces, triggering the soft palate and tongue to be positioned backwards which eventually results in minimizing the airway dimensions.[5] As a result, it became clear that patients having Angle Class II division 1 malocclusion had more narrow pharyngeal airways. [6,7]

It has been established that the optimum course for early management of skeletal Class II malocclusion caused by mandibular retrognathism is the utilization of functional appliances either fixed or removable. These appliances promote the advancement of the mandible while combating the obstruction of the airways through sleep. [8,9]

Removable functional appliances are effective, but their success depends much on the patient's cooperation to get predictable results within a realistic duration. The level of patient cooperation can vary and may not always be affordable, particularly when it comes to using appliances like headgear or removable functional appliances.[10] On the other hand, fixed functional appliances had recently gained popularity to address this problem during the late mixed or early permanent dentitions. Among them are the X-Bow and Forsus, which are innovative compliance-free fixed functional appliances. Compared to Forsus, X-Bow is capable of expanding the maxillary arch while positioning the mandibular arch forward, as it features a Hyrax expander with a fixed Class II corrector.[11] Thus, it has a likelihood of improving the airway by redirecting the mandibular growth direction into a more desirable one, and by decreasing the nasal resistance post rapid maxillary expansion.[12,13]

Orthodontic research has recently focused on the interplay between pharyngeal structures and various treatment modalities. Nevertheless, there is barely any agreement about the impact of fixed functional appliances upon the air way dimensions. While studies had demonstrated substantial improvements, others indicate no significant alterations in the pharyngeal dimensions.[14–17]

The lateral cephalometric radiograph that is routinely taken as a tool for diagnosis of orthodontic cases is an invaluable method for airways assessment. It is an inexpensive, simple, reproducible method with minimum radiation exposure compared to cone-beam computed tomography (CBCT). Likewise, the literature strongly supports the use of lateral cephalograms as a reliable tool for diagnosis and treatment planning, in terms of airway assessment. [18–21]

Based on available evidence, no study has compared the role of X-Bow and Forsus Fatigue Resistant Device (FFRD) on enhancing airway dimensions. Thus, this retrospective study aimed to estimate the oropharyngeal airway space changes following treatment with the Xbow versus Forsus appliances. The null hypothesis claimed that no variances in airway space effects between both treatment modalities.

Materials and Methods

Sample Size Calculation

The sample size computed to ascertain the minimum number of subjects enough to determine a difference of 1.5 mm[14] (±1.4 mm) in the upper pharyngeal dimension, with 0.05 significance, and a 80% statistical power. The analysis was performed using the G* Power software developed by Universität Düsseldorf, Germany. The suggested sample size per group was 21 subjects.

Study Setting

This study was ethically granted by the ethical committee at the faculty of dentistry, Tanta University, Egypt with code (#R- ORTH-7-24-3126). A pretreatment (T1) and posttreatment (T2) sample of 63 treated patients was selected from patients who completed their orthodontic treatment at Orthodontic department, Tanta University, Egypt and private orthodontic practice as follow; group I: 21 patients (15 girls, 6 boys, mean age: 13±2.4) previously treated with Xbow, Group II: 21 patients (13 girls, 8 boys, mean age: 12±3.1) previously treated with Forsus, and Group III: 21 class II patients (12 girls, 9 boys, mean age: 13±1.8) received no orthodontic treatment as control. Patients have been selected in accordance to the following criteria: Class II malocclusion before treatment, circumpubertal growth stage (CVM III and IV), no permanent teeth were extracted during treatment, Class I occlusion after treatment. The patient has pre- and post-treatment cephalograms of high-quality, and there is no medical history that could potentially impact the normal growth of the mandible. Patients were not eligible if any appliances other than Xbow or Forsus were used for Class II correction. After thoroughly explaining the treatment protocols to each participant, written informed consent and assent forms were collected from the patients and their guardians.

Interventions

Group I (Xbow appliance): This investigation utilized the standard Xbow™ fixed Class II corrector. It was composed of up of three main components: ForsusTM springs (3M Unitek, Monrovia, Calif.), mandibular buccal and lingual bows, and a maxillary Hyrax expander. The maxillary Hyrax featured banding the upper first molars and occlusal rests on first premolars. The Forsus™ EZ was installed, as per the manufacturer's directions, into the upper first molar band at one end, whereas looped around the labial bow nearby the mandibular canine at the other end. A Gurin lock (3M Unitek) on the lower labial bow restricted the forward movement of the Forsus™ spring. The lower buccal and lingual bows passively contact the lower incisors and secured by bands on the first molars. (Fig. 1)

Group II (Forsus appliance): Patients underwent non extraction treatment using MBT brackets (0.022", Ormco Corp, Calif). Leveling was performed until passive engagement of stainless-steel arch wires (0.019 × 0.025-inch) into both arches. The arch wires were cinched back, and teeth were figure-8 ligated. Maxillary trans palatal arch reinforcement was implemented to avoid buccal tipping of maxillary molars. The Forsus appliance was chosen and installed in conformity with the manufacturer's directions. (Fig. 2)

Patients were monitored at four-week intervals. Reactivation, if needed, can be accomplished through fixing Forsus split crimps onto the push rod. The FRD was removed once an incisor relationship with edge-to-edge contact obtained with a typical or overcorrected Class I canine and molar relationship.

Airway assessment:

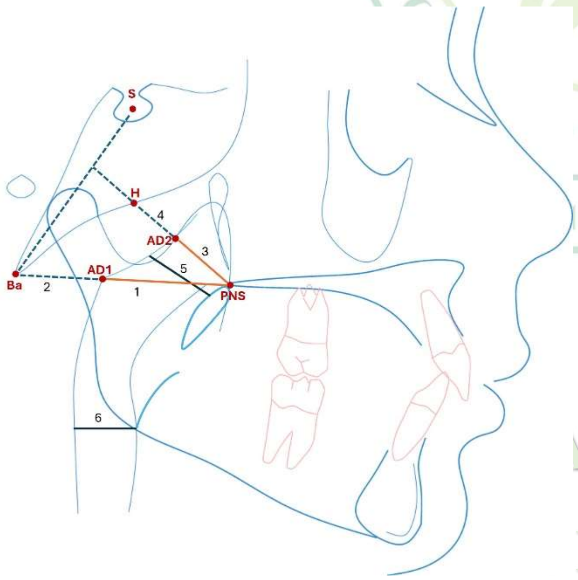
For the cephalometric analysis of airway dimensions, the pre and posttreatment cephalograms were digitized, and the following measurements were recorded (Table 1, Fig. 3) using Dolphin Imaging Program (Version 11.95, Chatsworth, Calif). [22]

Statistical Methods

SPSS version 23.0 (SPSS Incorporated, Chicago, Ill) was employed to conduct the statistical analysis. Mean and standard deviation were applied to indicate central tendencies and dispersion. The data showed normal distribution as indicated by the Shapiro-Wilk test. Accordingly, Paired *t*-tests were performed to assess changes over time. The ANOVA test was conducted to compare group differences. If significant differences were present ($P < .05$), a Tukey's multiple-comparison test was applied to pinpoint which groups had disparities.

Figure 1: Xbow fixed functional appliance in situ-occlusal upper and lower and frontal view.

Figure 2: Forsus fixed functional appliance in situ-lateral and frontal views



. Figure 3: Airway measurements.

Table 1: Description of Landmarks and measurements used for cephalometric airway analysis.

Landmark	Description
1- Lower airway thickness (PNS-AD1):	**Distance from the posterior nasal spine (PNS) to the closest point of adenoid tissue, along the PNS-Ba line (AD1).**
2- Lower adenoid thickness (AD1-Ba):	**Posterior nasopharyngeal wall thickness measured from AD1 to Basion point (Ba) along the PNS-Ba line.**
3- Upper airway thickness (PNS-AD2):	**Distance from the PNS to the nearby adenoid tissue along line drawn perpendicular from PNS to Sella-Ba (AD2).**
4- Upper adenoid thickness (AD2-H):	**Posterior nasopharyngeal wall thickness along the PNS-H line (H or Hormion is the meeting point between PNS perpendicular to S-Ba and the cranial base).**
5- Upper pharyngeal width [22]	**The smallest distance from the upper part of the soft palate to the closest point on the posterior pharyngeal wall.**
6- Lower pharyngeal width [22]	**The smallest distance from the point where the posterior tongue contour intersects with the mandible to the closest point on the posterior pharyngeal wall.**

Results

The treatment duration was significantly different between the two groups (*P*=0.003), with Group I (Xbow) having a mean duration of 21.19±3.74 months, while Group II (Forsus) showed a mean duration of 25.57±4.13 months.

For all examined cephalometric parameters, there were no significant differences observed among all three groups at T1 (Table 2).

Table 2 Comparison of the base line values of the air way measurements among all groups

Measurements	Group I		Group II		Group III		ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F	Sig
PNSAD1	18.63	1.73465	19.22	1.36284	18.69	1.23058	0.496	0.615
AD1Ba	19.79	1.56876	20.28	1.20074	19.72	0.80111	0.615	0.548
PNSAD2	13.01	1.25826	13.35	1.05751	13.01	0.85952	0.336	0.718
AD2H	14.97	0.48546	15.11	0.71872	14.36	1.48039	1.621	0.216
Upper airway	9.77	1.21751	10.21	0.64713	10.26	0.93119	0.788	0.465
Lower airway	15.02	0.4158	15.2	0.84853	14.94	0.87076	0.322	0.727

Table 3: Paired t-tests comparison of the changes over time in the tested groups.

Groups	Measurements	Pre		Post		Paired Samples Test			
		Mean	SD	Mean	SD	Mean	SD	t	Sig
Group I	PNSAD1	18.63	1.7346469	20.44	1.9850553	1.81	0.9206881	6.217	<.001
	AD1Ba	19.79	1.5687575	21.28	1.5824032	1.49	0.6723921	7.008	<.001
	PNSAD2	13.01	1.2582616	15.6	1.5740959	2.59	1.4137814	5.793	<.001
	AD2H	14.97	0.4854551	15.85	0.9991663	0.88	0.7714345	3.607	0.006
	Upper airway	9.77	1.2175111	10.87	1.1025727	1.1	0.2981424	11.667	<.001
	Lower airway	15.02	0.4157991	15.05	0.9766724	0.03	0.9117139	0.104	0.919
Group II	PNSAD1	19.22	1.3628402	19.45	2.1056801	0.23	0.8367264	0.869	0.407
	AD1Ba	20.28	1.2007405	21.34	0.7691265	1.06	1.0167486	3.297	0.009
	PNSAD2	13.35	1.0575128	14.55	1.2572015	1.2	0.915302	4.146	0.002
	AD2H	15.11	0.718718	16.66	0.9663218	1.55	0.6687468	7.329	<.001
	Upper airway	10.21	0.6471304	11.69	1.0928556	1.48	0.9052931	5.17	<.001
	Lower airway	15.2	0.8485281	15.75	0.7877535	0.55	0.3689324	4.714	0.001
Group III	PNSAD1	18.69	1.2305825	18.82	1.4335659	0.13	0.3743142	1.098	0.301
	AD1Ba	19.72	0.8011103	19.78	1.074761	0.06	0.5561774	0.341	0.741
	PNSAD2	13.01	0.8595218	12.7	0.8339997	-0.31	0.8543353	-1.147	0.281
	AD2H	14.36	1.4803903	14.9	0.8445906	0.54	0.8758488	1.95	0.083
	Upper airway	10.26	0.931188	10.1	0.5228129	-0.16	0.6801961	-0.744	0.476
	Lower airway	14.94	0.8707596	15.14	0.6535374	0.2	1.0022198	0.631	0.544

Table 4: Post Hoc Tukey's comparison among different groups.

Measurements	ANOVA		Tukey's Post Hoc Tests					
			Group I & II		Group I & III		Group II & III	
	F	Sig	Diff	Sig	Diff	Sig	Diff	Sig
PNSAD1	15.785	<.001	1.58000*	<.001	1.68000*	<.001	0.10000	0.952
AD1Ba	8.996	0.001	0.43000	0.439	1.43000*	<.001	1.00000*	0.020
PNSAD2	17.696	<.001	1.39000*	0.022	2.90000*	<.001	1.51000*	0.012
AD2H	4.379	0.023	-0.67000	0.150	0.34000	0.596	1.01000*	0.019
Upper airway	16.124	<.001	-0.38000	0.431	1.26000*	<.001	1.64000*	<.001
Lower airway	1.07	0.357	-0.52000	0.338	-0.17000	0.886	0.35000	0.605

Table 3 represents the results of the Paired *t*-tests to estimate the changes over time in different groups. The Xbow appliance demonstrated significant improvements in several parameters. The mean lower airway thickness (PNS-AD1) increased from 18.63 to 20.44 ($P < 0.001$), and lower adenoid thickness (AD1-Ba) increased from 19.79 to 21.28 ($P < 0.001$). Similarly, upper airway thickness (PNS-AD2) showed an increase from 13.01 to 15.60 ($P < 0.001$), and upper adenoid thickness (AD2-H) increased from 14.97 to 15.85 ($P = 0.006$). Upper pharynx dimension increased from 9.77 to 10.87 ($P < 0.001$). However, the lower pharynx dimension did not show significant changes ($P = 0.919$).

For the Forsus appliance, significant changes were observed in lower adenoid thickness, which increased from 20.28 to 21.34 ($P = 0.009$), and upper airway thickness, which increased from 13.35 to 14.55 ($P = 0.002$). Upper adenoid thickness increased from 15.11 to 16.66 ($P < 0.001$). Both upper and lower pharynx dimensions also showed significant increases, with upper pharynx dimension going from 10.21 to 11.69 ($P < 0.001$), and lower pharynx dimension from 15.20 to 15.75 ($P = 0.001$). However, lower airway thickness did not show a significant change ($P = 0.407$).

In contrast, the control group (untreated patients) showed no significant changes in most measurements. Lower airway thickness and lower adenoid thickness showed minimal changes that were insignificant ($P = 0.301$ and $P = 0.741$, respectively). Upper airway thickness slightly decreased, and upper adenoid thickness increased, but these changes were not significant ($P = 0.281$ and $P = 0.083$, respectively). Both upper and lower pharynx dimensions showed no significant changes ($P = 0.476$ and $P = 0.544$, respectively). These outcomes highlight the effectiveness of Xbow and Forsus appliances in improving airway dimensions relative to the control group, which was used to assess whether the observed changes were attributable to growth or treatment.

Further analysis with post hoc tests (Table 4) showed significant differences between Xbow and Forsus appliance ($P < 0.001$), and between the Xbow appliance and the control group ($P < 0.001$) in lower airway thickness and upper airway thickness measurements, indicating that the Xbow appliance had a more substantial impact on these parameters. For lower adenoid thickness, significant differences were seen when comparing the Xbow appliance and the control group ($P < 0.001$), and the Forsus appliance and the control group ($P = 0.020$), indicating that both appliances significantly improved this measurement compared to the control. The upper pharynx dimension revealed significant differences amongst both appliance groups and the control ($P < 0.001$), but not among both appliance groups themselves ($P = 0.431$). For upper adenoid thickness, a significant difference was observed between the Forsus appliance and the control group ($P = 0.019$), suggesting the Forsus appliance significantly improved this measurement. No significant differences were detected in lower pharynx dimensions across the groups ($P = 0.357$).

Discussion

Class II malocclusion due to mandibular retrognathia is among the most prevalent malocclusions seen in clinical orthodontic practices.[3] Functional appliances are predominantly employed in skeletal class II patients to induce mandibular repositioning. This repositioning can indirectly enlarge the airway space. However, the dimensions of the airway space continue to exhibit diverse results following functional treatment.[17,24] The need for precise understanding concerning the influence of functional appliances upon airway dimensions led to conducting the current study. Hence patient compliance is crucial during treatment, this study compared two popularly used, innovative compliance-free fixed functional appliances (X-Bow and Forsus).

In this study evaluation was conducted with lateral cephalograms where pharyngeal structures can be accurately evaluated.[19] In addition to the advantage of relatively low radiation doses, low cost, and the routine demand for orthodontic diagnosis and treatment planning.

Despite employing a retrospective design, the current investigation adhered to a rigorous categorization of patients enrolled in the study. In addition, a carefully matched control group was chosen to discriminate between growth and actual treatment outcomes. This was clarified from the baseline parameters (T1), that showed no significant differences among all three groups.

The treatment duration was significantly shorter in patients treated by Xbow as compared to Forsus. This shorter duration comes in accordance with the findings of Miller et al,[25] who found an average difference of 6 to 10 months between both appliances.

The results indicate a noticeable improvement in upper airway dimensions subsequent to fixed functional treatment with both Xbow and Forsus In contrast to the control group. The outcomes demonstrate the impressive efficacy of the Xbow and Forsus appliances in enhancing airway dimensions. Prior studies have indicated that the alterations of the airway caused by fixed functional treatment are the result of mandibular advancement. This advancement causes the tongue and soft palate to move forward, resulting in an enlargement of the upper airway dimensions.[26]

These findings align with a prior investigation by Abdalla et al,[27] who concluded a notable increase in the upper airway following fixed functional treatment in contrast to the control group. Ozdemir et al,[17] on the contrary, did not detect any significant alterations in the airway following treatment.

The Xbow appliance significantly improved all evaluated parameters (upper and lower airway thickness, upper and lower adenoid thickness, and upper pharynx dimension), with the exception of the lower pharynx dimension, which showed no significant changes across the groups. Consistent with the findings of this study, Erbas et al,[14] demonstrated that the Xbow appliance led to a beneficial enhancement in the dimension of the oropharyngeal airways. Whereas Atik et al,[11] revealed no substantial enhancement in the airway dimensions following Xbow treatment.

Regarding the Forsus appliance, there were notable changes observed in the thickness of the upper airway, upper and lower adenoids, and dimensions of the upper and lower pharynx. Nevertheless, there was no significant alteration in lower airway thickness. This partially agreed to Shetti et al;[28] who evaluated the effects of Forsus and determined that it resulted in a considerable increase in both upper and lower airway dimensions. These findings contradicted the conclusions of Kaur et al,[29] who found that Forsus appliance did not significantly affect the pharyngeal dimensions. One possible reason for this variation could be the utilization of different methods for airway analysis.

The null hypothesis was partially rejected as the Xbow was found to have greater impact on both lower and upper airway thickness measurements than Forsus and the control group. This finding can be related to the simultaneous rapid maxillary expansion concurrent with Xbow treatment that further decrease the air way resistance.[12,13]

This study had some limitations as it was not feasible to assess the mediolateral width and volume of the airway using lateral cephalometric radiographs. Additionally, this study demonstrated the immediate impacts of the two tested fixed functional appliances, but further investigation is essential to confirm the long-term sustainability of the acquired outcomes. However, this study has great clinical significance in the field of orthodontics, as enhancing the airway is crucial for patients with breathing disorders caused by mandibular retrognathism, improving the overall function and quality of life.

Conclusions

1. Both Xbow and Forsus treatments yielded positive results in enhancing the oropharyngeal airway measurements in class II patients in comparison to the matched untreated control group.
2. Xbow showed an additional impact on both upper and lower airway thickness measurements compared to Forsus.

Declarations

Funding

The authors received no funding from any organizations.

Data Availability

Data are available upon request to the corresponding author.

Ethical approval

This study was ethically granted by the ethical committee at the faculty of dentistry, Tanta University, Egypt with code (#R- ORTH-7-24-3126).

Competing interests

The authors revealed no conflicts of interest related to this study.

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