Dentoskeletal and airway effects of the X-Bow appliance versus removable functional appliances (Frankel-2 and Trainer) in prepubertal Class II division 1 malocclusion patients

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Objectives: The aim of the present study was to evaluate the dentoskeletal and airway effects of three different functional appliances (Frankel-2, Trainer and X-Bow) in prepubertal Class II division 1 patients.
Methods: The sample consisted of 54 patients with a Class II relationship as a result of mandibular retrognathia and relative maxillary constriction. Group I included 15 patients treated with a Frankel-2 appliance. Group II consisted of 14 patients treated with a T4-K Trainer. Group III consisted of 15 patients treated with the X-Bow appliance. Group IV consisted of 10 untreated Class II patients who served as a control group. Pretreatment (T1) and post-treatment (T2) cephalograms were used to evaluate dentoskeletal and airway changes. Parametric one-way variance analysis (ANOVA) and a paired *t*-test were used to perform statistical analysis.
Results: The decrease in SNA angle was significant in groups I and III, compared with the control group ($p < 0.05$). SNB angle and Co-GN length changes from T1 to T2 were statistically significant in groups I and II ($p < 0.05$), but not relative to the control group. The upper and lower incisors were significantly retruded and protruded, respectively, in all treatment groups ($p < 0.05$). Except PNS-AD2 and MAS measurements in group I, nasopharyngeal and oropharyngeal airway dimensions did not significantly change from T1 to T2 in all groups.
Conclusions: The Frankel-2 and X-Bow appliances were efficient in restricting the forward growth of the maxilla. The Frankel-2 and Trainer appliances produced a larger sagittal increase in mandibular length than the X-Bow appliance. Lower incisor proclination was more pronounced in the X-Bow group. The effect of the treatment protocols was similar and matched the control group with respect to the airway.
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Introduction

A Class II malocclusion originating from mandibular retrognathia may be treated by the use of functional appliances in an attempt to stimulate mandibular growth.[1] In company with the mandibular retrognathia, a constriction of the maxillary arch is encountered involving significantly reduced intercanine and intermolar widths.[2-4] Clinicians may therefore choose a functional appliance that offers maxillary expansion as one of its effects. Correspondingly, a popular removable functional appliance to manage mandibular deficiency and maxillary constriction is the functional regulator (FR-2).[5] A trainer is also claimed to correct a skeletal Class II malocclusion by providing a mandibular protrusive force.[6] The Frankel and Trainer appliances are also considered to produce transverse maxillary expansion by including buccal 'shields', which induce muscle relaxation of the dental arches.[7,8]

Besides removable functional appliances such as the

Frankel and Trainer, the X-Bow is a novel compliance-free, fixed, functional appliance used for the treatment of Class II problems in the late mixed or early permanent dentition.[9] With the use of the X-Bow appliance, the maxillary arch may be expanded and the mandibular arch can be positioned forward as the appliance includes a Hyrax expander and a fixed Class II corrector.

An anterior displacement of the mandible via a functional appliance is known to possibly influence the upper airway dimension by altering the final position of the hyoid bone and tongue.[10] A number of studies have therefore been conducted to verify the effects of variable Class II functional appliances on upper airway dimensions.[11-14]

To the best of current knowledge, no study has yet compared the effects of two commonly used patient compliance-dependent, removable appliances (Frankel-2 and Trainer) with the compliance-free, fixed, functional X-Bow appliance with regard to the management of mandibular position and improvement in upper airway dimension. Therefore, this retrospective and controlled study aimed to evaluate the treatment effects of three different functional appliances (Frankel-2, Trainer and X-Bow) on the dentoskeletal and upper airway dimensions in Class II division 1 patients presenting with relative maxillary constriction and mandibular retrognathia.

Materials and methods

The sample consisted of 54 Class II Caucasian patients selected from the archive of the Orthodontic Department of Hacettepe University. The study was conducted in accordance with the ethical Board of Hacettepe University with GO number 15/586-13.

The patient selection and inclusion criteria comprised (1) a skeletal Class II division 1 malocclusion with mandibular retrognathia (SNB<78°) and relative maxillary constriction, (2) early or late mixed dentition period, (3) prepubertal growth stage, (4) overjet ≥ 4 mm, (5) bilateral Class II or end-to-end molar and canine relationships, (6) age at the start of treatment between 8 and 12 years, and (7) no congenital craniofacial deformities.

The first treatment group consisted of 15 patients (11 females and 4 males) with a mean age of 8.94 ± 1.28 years and was treated with a Frankel-2 functional regulator appliance. A single-step mandibular advancement was conducted to an edge-to-edge incisor relationship with 2–3 mm of bite opening during wax-bite registration. The patients were instructed to wear the appliance full time (24 h/day) except for eating and oral hygiene measures. The patients were reviewed once every four weeks, and treatment was discontinued when the overjet and the overbite were reduced to 1–2 mm.

The second group consisted of 14 patients (six females and eight males) with a mean age of 8.79 ± 0.72 years who were treated with a preorthodontic T4-K (Myofunctional Research Co., QLD, Australia) Trainer. The patients were instructed to wear the appliance every day for three hours and overnight in accordance with the manufacturer's instructions. The patients were reviewed every six weeks until the overjet and the overbite were reduced to 1–2 mm.

The third group consisted of 15 patients (nine females and six males) with a mean age of 10.58 ± 1.27 years who were treated with the X-Bow appliance. The maxilla was expanded with a Hyrax screw attached to bands cemented on the first premolars and molars. The expander was part of the X-Bow fixed Class II corrector. After the maxillary expansion was achieved, a lower 1.10 millimetre round stainless steel anchorage arch and Guerin locks (3M Unitek large size) were placed, and 3M Unitek Forsus Fatigue-Resistant Device (FRD) with springs was inserted bilaterally and adjusted to supply 200 gm of force. The springs were reactivated every six weeks until the maxillary molars were in an overcorrected half-cusp Class III relationship.

The control group consisted of 10 subjects (four females and six males) with a mean age of 9.27 ± 0.89 years. The subjects did not receive any orthodontic treatment but were reviewed for approximately one year. The number of subjects in this group was fewer compared with the treatment groups, as finding non-treated Class II patients was difficult for ethical reasons. These subjects refused treatment at the initial visit but were followed up until the final diagnostic recordings were available.

Two lateral cephalograms were taken for each patient, one before treatment (T1) and one at the end of the functional appliance treatment (T2). All lateral radiographs were scanned and uploaded into Quick Ceph Studio software (Quick Ceph System 2014, CA, USA). The radiographs were traced and analysed by one investigator (EA) and controlled for accurate landmark identification by a second investigator

(HGC). The cephalometric analysis included 10 angular and 17 linear variables (Figures 1, 2 and 3).

Statistical analysis

IBM-SPSS for Windows software, version 21 (SPSS Inc., IL, USA) was used to perform descriptive and analytical statistical analysis. The Shapiro-Wilk test was applied to evaluate whether the distributions of difference values (difference between final and initial values) of variables were normal.

Demographic variables were assessed by a parametric one-way variance analysis (ANOVA) and used to determine the intergroup differences. The Levene test was applied to determine variance homogeneity assumption across groups of variables, while Welch's ANOVA test was used for those variables whose variance homogeneity assumption was not met.

For post-hoc analysis, LSD (Least Square Difference) and Tamhane's T2 tests were used to identify the group, which produced the difference. The LSD test was used for the variables that met the variance homogeneity assumption, while Tamhane's T2 was used for variables for which the variance homogeneity assumption was not met.

To evaluate the statistical significance of the dependent data between pretreatment and post-treatment periods within the groups, a paired *t*-test was applied.

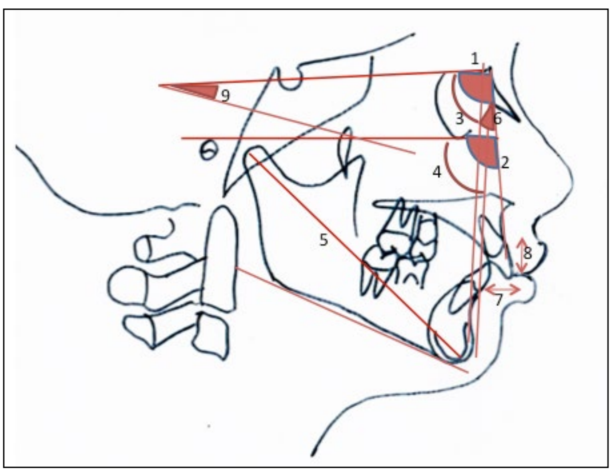

Figure 1. 1.SNA(°): angle between NA and SN plane; 2.Maxillary depth(°): angle between NA and FH plane; 3.SNB(°): angle between the NB line and SN plane; 4.Facial depth(°): angle between N-Pg line and FH plane; 5.Co-Gn (mm): mandibular length between points Co and Gn; 6.ANB(°): angle between NA and NB lines; 7.Overjet (mm): distance between the incisal edges of the maxillary and mandibular central incisors, parallel to the occlusal plane; 8.Overbite (mm): distance between the incisal edges of the maxillary and mandibular central incisors, perpendicular to the occlusal plane; 9.GoGnSN(°): angle between the SN plane and the mandibular plane angle.

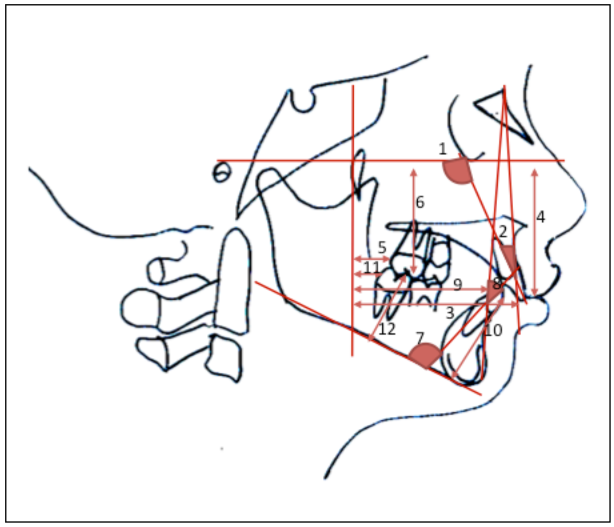

Figure 2. Dental cephalometric measurements.
1.U1-FH(°): angle between the axis of the upper incisor and FH line; 2.U1-NA(°): angle between the axis of the upper incior and NA line; 3.U1-PTV (mm): the distance between the tip of the upper incisor and PTV; 4.U1-FH (mm): the distance between the tip of the upper incisor and FH plane; 5.U6-PTV (mm): the distance between the most distal point of the distal contour of the upper molar and PTV; 6.U6-FH (mm): the distance between the tip of the mesiobuccal cusp of the upper molar and FH plane; 7.IMPA(°): angle between the axis of the lower incisor and the mandibular plane angle; 8.L1-NB(°): angle between the axis of the lower incisor and NB line; 9.L1-PTV (mm): the distance between the tip of the lower incisor and PTV; 10.L1-MP (mm): the distance between the tip of the lower incisor and mandibular plane; 11.L6-PTV (mm): the distance between the most distal point of the distal contour of the lower molar and PTV; 12.L6-MP (mm): the distance between the tip of the mesiobuccal cusp of the lower molar and mandibular plane.

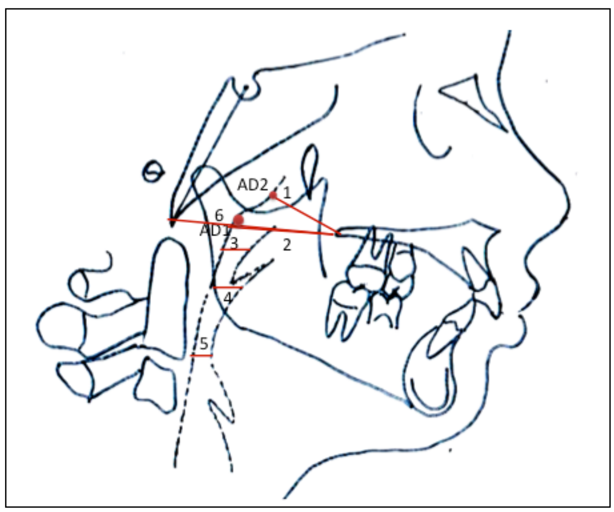

Figure 3. Cephalometric measurements of the upper airway.
1.PNS-AD2 (mm): the distance between PNS and AD2, which is a point on posterior pharyngeal wall intersecting H-PNS line; 2.PNS-AD1 (mm): the distance between PNS and AD1, which is a point on posterior pharyngeal wall intersecting Ba-PNS line; 3.SPAS (mm): the line parallel to horizontal plane between the middle point of PNS and P and posterior pharyngeal wall; 4.MAS (mm): the line extending to anterior and posterior pharyngeal walls from P point; 5.IAS (mm): the line parallel to horizontal plane and passing through the anteroinferior point of CV2 and anterior pharyngeal wall; 6.Ba-PNS (mm): the distance between Ba and PNS points.

For all variables, mean and standard deviation values were used as descriptive statistics. A *p*-value less than 0.05 was considered statistically significant.

Results

The mean age of the subjects, duration of the treatments and ANB angle measurements are provided in Table I. The initial age and treatment durations were significantly different between the groups. The mean duration of treatment of group III was significantly less than that in groups I, II and IV ($p < 0.05$). However, the age of the patients in group III was significantly older than that of the other groups ($p < 0.05$).

Skeletal changes between T1 and T2 and the comparison of these changes between the groups are presented in Tables II and III. Maxillary depth did not significantly change in all groups. A statistically significant decrease in SNA angle in groups I and III of 0.58° and 0.92°, respectively, was noted. The mandibular sagittal positional change related to the SNB angle and Co-GN measurements from T1 to T2 period was significant in groups I, II and IV (Table II, $p < 0.05$). The increase in Co-GN measurement was significantly greater in groups I (3.95 mm), II (3.41 mm) and IV (4.54 mm) than in group III (0.53 mm) (Table III, $p < 0.05$). ANB and overjet measurements significantly reduced by the end of treatment in all treatment groups (I, II and III) (Table II, $p < 0.05$). Changes in the overbite and GoGn-SN measurements were not significant, and no differences were found in these changes between the groups (Tables II and III, $p < 0.05$).

All dentoalveolar changes are presented in Tables III and IV. The upper incisors were significantly retruded, and the lower incisors were significantly protruded in all groups except the control group (Table IV, $p < 0.05$). The decrease in U1–FH and U1–NA angles was significantly greater in group I than in group III. These measurements also showed a significant decrease in all treatment groups compared with the control group (Table III, $p < 0.05$). Changes in the lower incisor inclination were significantly different from each other between groups I and III, II and III, I and IV and III and IV (Table III, $p < 0.05$). The forward movement of L6 and L1 relative to the PTV plane was significant in three different treatment groups (Table IV, $p < 0.05$). The palatal movements of U1 relative to the FH plane significantly increased in all treatment groups, and the movement of U6 significantly increased in groups II and III. The lower incisors significantly extruded in group II and significantly intruded in group III. The vertical movement of the lower molars significantly increased in all treatment groups (Table IV). U1–FH and L1–MP measurement changes significantly differed between groups I and III, I and IV and II and IV for U1–FH and between groups II and III and III and IV for L1–MP (Table III, $p < 0.05$).

The results of the upper airway analysis are presented in Tables III and V. Except for the PNS-AD2 and MAS

Table I. Demographic and clinical characteristics of the sample.

Variables	Group I (Frankel-2)	Group II (Trainer)	Group III (X-Bow)	Group IV (Control)	*p*-value
Number of subjects	15 (11 female, 4 male)	14 (6 female, 8 male)	15 (9 female, 6 male)	10 (4 female, 6 male)	
Age (year)	8.94±1.28	8.79±0.72	10.58±1.27	9.27±0.89	p = 0.000 (I-III) p = 0.000 (II-III) p = 0.000 (III-IV)
Treatment duration (year)	1.19±0.20	1.19±0.33	0.72±0.19	1.23±0.16	p = 0.000 (I-III) p = 0.000 (II-III) p = 0.000 (III-IV)
ANB°	6.32±2.05	6.36±2.02	6.25±1.98	5.96±0.87	$p > 0.05$

Parametric one-way variance analysis (ANOVA) and LSD analysis
Values are presented as mean ± standard deviation (SD) or *p*-value.

measurements, which increased significantly in group I, the nasopharyngeal (PNS-AD1, PNS-AD2 and Ba-PNS) and oropharyngeal airway dimensions (SPAS, MAS and IAS) did not significantly change from the T1 to T2 period in all groups (Table V, $p > 0.05$). Intergroup comparisons indicated that the changes in the airway dimensions did not differ between the groups (Table III, $p < 0.05$).

Discussion

Although using a retrospective design, the present study followed a strict classification of patients included in the treatment groups. Moreover, a well-matched control group was selected to eliminate growth effects from true treatment effects. The patients were treated by different clinicians, which could be considered as a limitation of the study. Nevertheless, the clinicians were educated and correspondingly trained in the same clinic. The subjects in the three different treatment groups were at a pre-peak or peak pubertal growth stage (CS2 and CS3), determined using the cervical vertebral maturation method.[15]

McNamara and Brudon[16] suggested maxillary expansion in Class II malocclusion patients to manage the relative maxillary constriction and facilitate the forward movement of the mandible. Relative

Table II. Pre- (T1) and post-treatment (T2) skeletal measurements of each group.

Variables	Group I	*p*	Group II	*p*	Group III	*p*	Group IV	*p*
SNA°		0.008*		0.664		0.037*		0.038*
T1 (mean±SD)	79.73±2.90		78.11±1.71		80.01±2.67		78.11±2.69	
T2 (mean±SD)	79.15±3.09		78.01±1.68		79.09±2.54		78.88±2.71	
Max. depth°		0.109		0.956		0.056		0.308
T1 (mean±SD)	88.65±2.00		88.83±1.72		90.33±3.02		89.56±2.59	
T2 (mean±SD)	88.16±1.77		88.81±1.73		89.45±2.65		88.51±2.04	
SNB°		0.000*		0.019*		0.108		0.005*
T1 (mean±SD)	73.39±3.96		71.75±2.49		73.55±2.27		72.14±2.02	
T2 (mean±SD)	74.95±3.70		72.54±2.39		74.14±2.58		73.61±2.30	
Facial depth°		0.143		0.171		0.153		0.783
T1 (mean±SD)	83.82±2.65		83.34±2.61		85.13±1.61		85.66±2.62	
T2 (mean±SD)	84.30±2.53		83.86±2.66		85.24±2.45		85.40±2.39	
Co-GN (mm)		0.003*		0.009*		0.358		0.009*
T1 (mean±SD)	97.55±6.59		97.26±5.26		102.61±4.46		100.23±4.0	
T2 (mean±SD)	101.49±7.93		100.68±6.08		103.15±5.91		104.77±5.14	
ANB°		0.000*		0.002*		0.001*		0.005
T1 (mean±SD)	6.32±2.05		6.36±2.02		6.25±1.98		5.96±0.87	
T2 (mean±SD)	4.69±1.88		5.61±1.95		4.95±1.89		5.28±0.89	
Overjet (mm)		0.000*		0.000*		0.000*		0.598
T1 (mean±SD)	9.18±2.26		7.56±1.72		9.08±1.54		9.60±2.33	
T2 (mean±SD)	4.05±1.62		4.08±2.79		4.56±0.89		9.93±3.09	
Overbite (mm)		0.939		0.708		0.164		0.001*
T1 (mean±SD)	1.90±2.43		1.25±1.91		1.98±1.89		0.92±1.67	
T2 (mean±SD)	1.95±1.55		1.42±1.55		1.40±1.62		2.10±2.14	
GoGnSN°		0.191		0.307		0.758		0.462
T1 (mean±SD)	33.83±5.88		37.67±4.32		36.46±5.04		33.75±5.88	
T2 (mean±SD)	34.39±6.12		36.92±5.37		36.32±5.31		33.30±7.05	

Paired *t*-test, comparison of pre- and post-treatment measurements within groups, the significance level was $p < 0.05$,*Statistically significant.

Table III. Comparison of measurement changes during treatment in each group.

Variables	Group I (mean±SD)	Group II (mean±SD)	Group III (mean±SD)	Group IV (mean±SD)	I-II p	I-III p	II-III p	I-IV p	II-IV p	III-IV p
SNA°	-0.58±0.73	-0.1±0.84	-0.92±1.55	0.77±1.00	NS	NS	NS	0.014*	NS	0.018*
Max. dep.°	-0.49±1.10	-0.02±1.42	-0.88±1.63	-1.05±3.08	NS	NS	NS	NS	NS	NS
SNB°	1.55±0.62	0.79±1.10	0.59±1.32	1.47±1.27	NS	NS	NS	NS	NS	NS
Fac. dep.°	0.48±1.22	0.52±1.35	0.11±0.33	-0.26±2.90	NS	NS	NS	NS	NS	NS
Co-GN (mm)	3.95±4.35	3.41±4.16	0.53±2.04	4.54±4.30	NS	0.017*	0.046*	NS	NS	0.012*
ANB°	-1.63±0.71	-0.75±0.72	-1.30±1.62	-0.68±0.59	0.010*	NS	NS	0.012*	NS	NS
Overjet (mm)	-5.13±1.74	-3.49±2.03	-4.52±1.60	0.33±1.91	0.018*	NS	NS	0.000*	0.000*	0.000*
Overbite (mm)	0.040±2.00	0.17±1.68	-0.57±1.51	1.18±0.77	NS	NS	NS	NS	NS	NS
GoGnSN°	0.56±1.58	-0.75±2.64	-0.14±1.72	-0.45±1.85	NS	NS	NS	NS	NS	NS
U1-FH°	-9.25±4.36	-6.78±5.39	-3.54±3.20	0.54±5.61	NS	0.001*	NS	0.000*	0.000*	0.036*
U1-NA°	-8.29±3.91	-6.75±5.20	-2.65±2.52	1.71±4.51	NS	0.000*	0.010*	0.000*	0.000*	0.012*
U1-PTV (mm)	-1.44±3.42	-0.07±2.90	-0.83±1.61	1.04±3.05	NS	NS	NS	NS	NS	NS
U1-FH (mm)	-2.37±1.58	-3.46±2.91	-1.36±1.84	-2.89±2.51	NS	0.002*	NS	0.002*	0.028*	NS
U6-PTV (mm)	0.75±1.65	1.61±1.70	0.68±0.97	0.38±1.39	NS	NS	NS	NS	NS	NS
U6-FH (mm)	-1.57±2.05	-3.04±2.59	-0.94±1.82	-1.99±0.76	NS	NS	NS	NS	NS	NS
IMPA°	4.01±3.45	3.22±4.10	10.73±4.06	1.57±4.60	NS	0.000*	0.000*	NS	NS	0.000*
L1-NB°	5.35±3.32	3.09±4.34	11.29±4.56	0.95±4.06	NS	0.000*	0.000*	0.011*	NS	0.000*
L1-PTV (mm)	2.10±2.55	3.86±4.34	2.56±1.63	1.56±2.82	NS	NS	NS	NS	NS	NS
L1-MP (mm)	0.43±1.66	1.34±2.29	-0.83±1.36	1.15±1.77	NS	NS	0.002*	NS	NS	0.009*
L6-PTV (mm)	1.10±1.58	1.58±1.72	1.71±0.91	0.94±1.46	NS	NS	NS	NS	NS	NS
L6-MP (mm)	1.44±1.74	1.65±1.91	1.29±0.78	1.02±1.46	NS	NS	NS	NS	NS	NS
PNS-AD2 (mm)	1.79±3.10	0.53±2.94	1.12±3.76	0.51±2.64	NS	NS	NS	NS	NS	NS
PNS-AD1 (mm)	2.09±4.78	0.39±4.23	0.27±4.48	-0.09±2.89	NS	NS	NS	NS	NS	NS
SPAS (mm)	0.53±1.40	0.79±2.48	0.39±3.23	0.02±1.31	NS	NS	NS	NS	NS	NS
MAS (mm)	0.69±1.00	0.59±1.79	0.41±3.46	0.58±1.22	NS	NS	NS	NS	NS	NS
IAS (mm)	0.47±1.71	0.76±2.26	0.61±4.86	0.51±2.02	NS	NS	NS	NS	NS	NS
Ba-PNS (mm)	1.74±3.35	1.76±3.71	-0.43±3.20	0.28±2.41	NS	NS	NS	NS	NS	NS

One-way variance analysis (ANOVA), LSD and Tamhane's T2 of post-hoc test, comparison of groups. The significance level was $p < 0.05$. *Statistically significant. I-II. Group I and Group II comparison; I-III. Group I and Group III comparison; II-III. Group II and Group III comparison; I-IV. Group I and Group IV comparison; II-IV. Group II and Group IV comparison; III-IV. Group III and Group IV comparison. NS: nonsignificant

maxillary constriction may also lead to mandibular retrognathia.[17] In the present study, the selected functional appliances exhibited a common treatment feature, which was expansion of the maxillary arch, as a treatment requirement. However, the nature of the individual appliance expansion effects differed. The Frankel-2 and Trainer appliances were claimed to encourage passive transverse maxillary expansion by acting as a shield against cheek activity and by relaxing the muscles.[7,8] Alternatively, the Hyrax jackscrew enabled active posterior expansion with the X-Bow appliance system.[18]

The results of a systematic review[19] demonstrated clinically significant skeletal effects related to mandibular growth with removable functional appliances when treatment was performed during the pubertal growth phase instead of the prepubertal phase. In the present study, none of the appliances showed a significant increase in sagittal mandibular position compared with the control group, and this result may be correlated with the prepubertal growth phase of the patients. Similar results revealing minimal or no effects of Frankel-2 treatment on mandibular length have been presented by previous investigations.[20-22] In accordance

Table IV. Pre- (T1) and post-treatment (T2) dental measurements of each group.

Variables	Group I	*p*	Group II	*p*	Group III	*p*	Group IV	*p*
U1-FH°		0.000*		0.000*		0.001*		0.768
T1 (mean±SD)	117.79±6.88		114.56±7.27		114.85±5.00		117.02±7.26	
T2 (mean±SD)	108.54±5.57		107.79±7.51		111.31±4.98		117.56±5.29	
U1-NA°		0.000*		0.000*		0.001*		0.261
T1 (mean±SD)	28.67±6.02		25.75±6.60		24.53±6.15		27.44±6.29	
T2 (mean±SD)	20.37±5.55		10.9±7.5		21.87±5.94		29.15±5.49	
U1-PTV(mm)		0.126		0.928		0.066		0.309
T1 (mean±SD)	50.54±4.13		49.86±2.71		54.64±3.88		53.49±3.86	
T2 (mean±SD)	49.10±5.36		49.79±3.30		53.81±3.66		54.53±3.73	
U1-FH (mm)		0.000*		0.001*		0.013*		0.005*
T1 (mean±SD)	-44.77±2.70		-45.24±2.31		-47.13±2.07		-44.25±3.83	
T2 (mean±SD)	-47.14±3.21		-48.70±3.16		-48.49±2.86		-47.14±4.95	
U6-PTV(mm)		0.101		0.004*		0.0171*		0.410
T1 (mean±SD)	28.23±1.73		28.84±2.07		28.19±2.28		29.52±1.07	
T2 (mean±SD)	28.97±1.74		30.45±2.95		28.87±2.26		29.90±1.57	
U6-FH (mm)		0.010*		0.001*		0.065*		0.000*
T1 (mean±SD)	-34.56±2.75		-33.86±2.24		-36.14±2.71		-35.47±2.68	
T2 (mean±SD)	-36.13±3.46		-36.90±2.72		-35.20±3.54		-37.46±2.38	
IMPA°		0.001*		0.011*		0.000*		0.309
T1 (mean±SD)	96.39±5.02		99.62±8.08		96.21±6.27		94.76±6.46	
T2 (mean±SD)	100.39±5.23		102.85±8.27		106.95±5.91		96.33±9.09	
L1-NB°		0.000*		0.021*		0.000*		0.478
T1 (mean±SD)	23.84±5.58		29.05±5.69		26.32±7.01		20.67±7.39	
T2 (mean±SD)	29.20±4.88		32.14±5.88		37.61±5.08		21.62±8.97	
L1-PTV (mm)		0.007*		0.005*		0.000*		0.114
T1 (mean±SD)	44.63±4.66		44.72±2.10		48.17±2.86		46.51±1.88	
T2 (mean±SD)	46.73±4.89		48.58±4.83		50.73±3.63		48.07±3.42	
L1-MP (mm)		0.329		0.047*		0.033*		0.070
T1 (mean±SD)	35.21±2.19		35.66±2.10		35.99±2.30		35.81±1.57	
T2 (mean±SD)	35.64±2.44		37.01±2.64		35.15±3.04		36.96±1.71	
L6-PTV (mm)		0.017*		0.004*		0.000*		0.072
T1 (mean±SD)	23.64±1.69		24.34±2.39		23.28±1.93		23.78±1.33	
T2 (mean±SD)	24.74±1.97		25.91±3.04		24.99±2.30		24.72±1.68	
L6-MP (mm)		0.006*		0.007*		0.000*		0.055
T1 (mean±SD)	22.38±2.34		23.44±2.05		23.09±1.88		23.28±1.14	
T2 (mean±SD)	23.82±2.17		25.09±3.05		24.38±2.26		24.30±1.53	

Paired *t*-test, comparison of pre- and post-treatment measurements within groups, the significance level was $p < 0.05$. *Statistically significant.

with the present result, Usumez et al. determined the effects of the preorthodontic Trainer appliance did not differ from the control group in relation to sagittal mandibular growth.[6] Similarly, Flores-Mir et al.,[18] Cope et al.[23] and Covell et al.[24] did not find significant change in the sagittal position of the mandible using fixed functional appliances. Conversely, with respect to the results of the present study, the Trainer and Frankel-2 appliances produced significantly greater increments in total mandibular length compared with the X-Bow appliance. The lack of mandibular skeletal growth in the X-Bow appliance group might have been due to the short duration of active treatment or the fact that the X-Bow appliance is a non-protrusive Class II corrector.[25]

Table V. Pre- (T1) and post-treatment (T2) airway measurements of each group.

Variables	Group I	*p*	Group II	*p*	Group III	*p*	Group IV	*p*
PNS-AD2 (mm)		0.043*		0.513		0.268		0.557
T1 (mean±SD)	16.37±4.15		15.43±3.62		19.25±4.01		15.55±2.73	
T2 (mean±SD)	18.15±4.32		15.96±3.72		20.37±4.13		16.06±4.08	
PNS-AD1 (mm)		0.112		0.734		0.821		0.924
T1 (mean±SD)	21.58±4.73		20.61±4.95		27.11±5.84		20.96±3.70	
T2 (mean±SD)	23.67±6.14		21.01±4.84		27.37±4.68		20.87±4.44	
SPAS (mm)		0.167		0.254		0.644		0.963
T1 (mean±SD)	9.40±2.02		8.42±1.96		13.31±2.41		9.22±2.73	
T2 (mean±SD)	9.93±1.64		9.21±1.09		13.70±2.28		9.24±2.35	
MAS (mm)		0.019*		0.237		0.650		0.167
T1 (mean±SD)	10.85±1.50		10.04±1.51		12.47±3.24		10.61±2.89	
T2 (mean±SD)	11.54±1.64		10.64±2.54		12.89±3.20		11.19±2.76	
IAS (mm)		0.309		0.233		0.636		0.445
T1 (mean±SD)	12.73±2.42		12.12±1.94		13.62±2.96		12.11±2.35	
T2 (mean±SD)	13.19±2.32		12.88±2.80		14.23±3.35		12.62±2.67	
Ba-PNS (mm)		0.064		0.098		0.613		0.722
T1 (mean±SD)	41.91±4.32		41.06±4.18		44.98±4.14		41.52±3.12	
T2 (mean±SD)	43.65±5.39		42.82±4.99		44.55±3.66		41.80±4.21	

Paired *t*-test, comparison of pre- and post-treatment measurements within groups, the significance level was $p < 0.05$. *Statistically significant.

The forward growth of the maxilla in the Frankel-2 and X-Bow groups was significantly less than that of the control group. A similar significant restraining effect on the maxilla by the Frankel-2 appliance was previously reported.[26-28] Flores-Mir et al.[18] described a posterior displacement of the maxilla of nearly 2.8 mm with the X-Bow appliance, which was greater than the restriction amount (0.92 mm) found in the present study. This maxillary restriction effect has also been reported as a result of FRD treatment, which incorporates a Class II corrector spring similar to the X-Bow appliance.[29-31]

The Frankel-2 and Trainer groups revealed greater upper incisor retroclination than the X-Bow group. The upper incisor retroclination was an expected result in the Frankel-2 group as the labial bow makes contact with the upper incisors when worn.[32,33] Moreover, the use of the Trainer appliance can eliminate oral dysfunction, establish muscle balance and produce a positive effect on maxillary incisor protrusion.[34] Therefore, a greater reduction in maxillary incisor inclination in the Frankel-2 and Trainer groups can be related to postural lip change and the increase in the upper lip muscle strength resulting from the myofunctional effects of these appliances. However, unlike the Frankel-2 and Trainer appliances, the X-Bow appliance does not incorporate any component that contacts with the upper incisor and does not eliminate oral dysfunction. In the Frankel-2 and Trainer groups, the upper incisors were significantly extruded relative to the FH plane compared with the control group. This result was mostly a result of the greater incisor retroclination in these groups compared with the X-Bow group.

The proclination of the mandibular incisors was three times greater in the X-Bow group than in the Frankel-2 and Trainer groups. Similar significant lower incisor proclination with fixed functional appliances was recorded by previous studies.[30,35] On the basis of this profound effect, clinicians are advised to choose a removable rather than a fixed functional appliance in patients with prominent labially-inclined lower incisors at the beginning of the treatment. Moreover, during the course of the second phase of fixed functional appliance treatment, the negative torque in the mandibular anterior brackets enables better control of the lower incisors. The lower incisors were also significantly intruded in the X-Bow group compared with the control and Trainer groups. The sagittal molar correction was mostly derived from the significant forward movement of L6 and L1 relative to PTV, instead of upper arch distalisation, which occurred in the treatment groups. This finding has a major impact on Class II molar correction.

Previous studies have compared fixed functional appliances with removable functional appliances with regard to dentoskeletal effects. Ehsani et al.[25] compared the effects of the Twin-block and X-Bow appliances and found a greater increase in mandibular incisor inclination using the X-Bow appliance and corpus length increase in the Twin-block group. Similar to the findings of Ehsani et al.,[25] the present study found a larger sagittal increase in the mandible in the Frankel and Trainer groups compared with the X-Bow group, while the X-Bow group experienced greater mandibular incisor proclination. Giuntini et al.[31] also compared removable (Twin-block) and fixed (Forsus) functional appliances in growing patients. Similar to the present study, a greater amount of maxillary incisor retroclination, and increased mandibular length, was found in the removable functional appliance group but not in the fixed functional appliance group. Bilgiç et al.[36] compared the Forsus Fatigue Resistant Device (FRD) EZ and an activator in actively growing patients and found similar results. A restraining growth effect on the maxilla was noted in both appliance groups, and greater mandibular incisor protrusion and intrusion were observed following the use of the FRD appliance.

With the forward displacement of the mandible through the use of functional appliances, the morphology of the upper airway may be influenced as a result of positional changes of the hyoid bone and tongue.[10] Aside from the dentoskeletal changes, the present study also evaluated airway changes, as few studies have been conducted on the airway effects of the Frankel-2, Trainer or X-Bow appliance. A statistically significant increase in airway measurements (PNS-AD2 and MAS) was observed only in the Frankel-2 group. In accordance with the present result, Gao et al.[37] investigated the effects of the Frankel-2 appliance and found improvement in the sagittal dimensions of the upper airway. The statistically significant increase observed only in the Frankel-2 group in the present study could be due to the greater forward movement of the mandible compared with other functional appliances. As a result of the use of the Trainer appliance, a child may be able to revert from oral to nasal breathing, and maintain nasal respiration. Nevertheless, in contrast, the Trainer appliance did not significantly increase the airway dimensions in the present study. An earlier study evaluated the airway effects of the X-Bow appliance without a control group and found a favourable increase in oropharyngeal airway dimensions and volume in contrast to the present results.[35] Removable (Frankel-2 and Trainer) and fixed (X-Bow) appliances did not differ from each other with regard to the identified nasopharyngeal and oropharyngeal airway changes. However, Jena et al.[38] found the removable functional appliance (Twin-block) more efficient than the fixed functional appliance (MPA-IV) in improving PAP dimensions in Class II subjects. Similar to the present finding, Kinzinger et al.[39] recommended that functional treatment for a Class II malocclusion was ineffective in improving breathing problems. Ozdemir et al.[40] also reported no significant change in oropharyngeal airway dimension in patients treated with a fixed functional appliance (FRD).

In treating patients with a Class II division 1 mandibular retrognathia who have relative maxillary constriction during the prepubertal growth phase, clinicians should be able to choose a functional appliance that also includes an expansion capability. Therefore, Frankel-2, Trainer and X-Bow appliances can be selected according to patients' needs and practice management. It is noteworthy that these appliances have comparable advantages and disadvantages. The Frankel-2 and Trainer appliances can act as reprogramming devices and enable a proper oral seal.[26,34] Therefore, these appliances are preferable to the X-Bow appliance, particularly in patients with a lower lip trap to establish muscle balance. The X-Bow appliance may apply active expansion to the maxillary arch, unlike the Trainer and Frankel-2 appliances that apply passive expansion. In patients with constricted arches, the X-Bow may be considered as a first choice. When the duration of the treatment protocols was assessed in the present study, the functional phase of treatment was significantly faster using the X-Bow appliance compared with the Frankel-2 and Trainer appliances. Obtaining patient compliance until the end of Class

II correction with removable appliances is difficult, and a failure to complete treatment was reported to be as high as 34% in a study conducted by O'Brien et al.[41] Moreover, the Frankel-2 and Trainer appliances can have a negative effect on speech and social activities, unlike fixed functional appliances. According to the results of the present study, the correction of the ANB angle and the overjet was greater in the Frankel-2 group than in the Trainer group. Therefore, the Frankel-2 appliance is preferable compared with other appliances when treating patients presenting with mandibular retrognathia and requiring a removable functional appliance.

Conclusions

Removable and fixed functional appliance treatment was effective in significantly reducing the ANB angle, overjet and improving molar relationships. These results were considered to be clinically significant.

None of the appliances produced a significant increase in sagittal mandibular position change compared with the control group. The Frankel-2 and Trainer appliances had a larger sagittal increase in total mandibular length compared with the X-Bow appliance.

The headgear effect of the functional appliances was significant in the Frankel-2 and X-Bow groups.

The most significant difference in the dentoalveolar effects in the treatment groups was the proclination of the mandibular incisors, which was greatest in the X-Bow group.

The maxillary incisors showed a significantly greater amount of retroclination in the Frankel-2 and Trainer groups compared with the X-Bow group.

Except for a significant increase in the PNS-AD2 and MAS measurements from the pretreatment to the post-treatment period in the Frankel group, the treatment protocols did not significantly differ from each other and the control group with respect to nasopharyngeal and oropharyngeal airway changes.

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