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ORIGINAL ARTICLE

Evaluation of Dentoskeletal and Pharyngeal Airway Changes after Treatment with Twin Block and Monoblock Appliance in Growing Patients

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ABSTRACT

Objective: To compare of pharyngeal airway dimensions and dentoskeletal changes after treatment with twin block (TWB) and monoblock (MB) appliance in growing patients. **Methods:** The sample was comprised of a total of 72 patients at the ages of 10 to 13. The TWB group consisted of 36 patients (22 females, 14 males, mean age: 11.9±1.5) and MB group consisted of 36 patients (18 females, 18 males, mean age: 11.8±1.2). The linear and angular measurements were evaluated on lateral cephalometric radiographs at beginning (T0) and end of treatment (T1). **Results:** The amounts of increase in the inferior airway space, L1xNB, IMPA and FMA measurements from T0 to T1 in the TWB group were significantly higher ($p < 0.05$).In the TWB group, the amounts of the increase in the soft palate thickness, distance between hyoid and C3, Co-A and Co-Gn measurements from T0 to T1 in the female patients were significantly higher ($p < 0.05$).In the MB group, the amounts of increase in the Upper adenoid thickness and Vertical airway length measurements from T0 to T1 in the female patients were significantly higher ($p < 0.05$). **Conclusion:** Both the MB and TWB appliances increase the pharyngeal airway dimensions, and the lower airway is most affected by the appliance type. The effects of the MB and TWB appliances on tongue dimensions and hyoid bone movements are different.

Key words: class II treatment, monoblock, pharyngeal airway, twin block

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INTRODUCTION

Different functional appliances have been used for a long time to change the direction and amount of mandibular growth in skeletal Class II malocclusions, which are characterized by the underdevelopment of the mandible.[1,2] While the Monoblock appliance consists of one-piece acrylic that connects mandibular and maxillary bite blocks on the occlusal plane, the Twin Block appliance consists of two acrylic pieces. The Twin Block appliance is a functional appliance that allows the mandible to be positioned downward and forward, and it consists of mandibular and maxillary bite blocks whose forward parts are in the form of sloped surfaces, and the blocks are locked with each other at an angle of 70°.[3,4]

Several researchers have stated that there is a relationship among craniofacial, dentofacial and pharyngeal structures, and a distal positioning of the mandible and maxilla may lead to a reduction in the anteroposterior dimensions of the airways.[5,6] Previous studies have shown that nasal airway narrowing is associated with the posterior rotation of the mandible, postero-superior growth of the condyles, a broad gonial angle and narrow arches.[6–8]

Many studies have reported that functional appliances improve the facial profile, fix the position of the mandible and lead to an increase in pharyngeal airway dimensions.[9,10] In patients who have pharyngeal airway narrowing, by the use of appliances providing mandibular advancement, there is an increase in the volume of the upper pharyngeal airway and the availability of oxygen.[11] In addition to this, these appliances have been reported to show their effect by forcing the mandible, tongue, soft palate and hyoid bone forward and increasing the dimensions of the bone and soft tissues around the oropharyngeal airway.[12–14]

In this study, it was aimed to investigate the skeletal, dentoalveolar and pharyngeal airway effects of the Twin Block and Monoblock appliances that are used in the treatment of Class II malocclusion in growing patients.

METHODS

This retrospective study was approved by Istanbul Aydın University Ethics Committee (2021/382). The study was conducted using good-quality cephalometric radiographs from patients who were admitted to Istanbul Aydın University Faculty of Dentistry - Department of Orthodontics.

Inclusion criteria: Skeletal Class II malocclusion (ANB > 4°), skeletal mandibular retrognathia, overjet ≥ 5 mm, normal ($28^0 \leq$ SN/GoGn $\leq 32^0$) or reduced (SN/GoGn < 28°) vertical facial growth, early or late mixed dentition, CVMI stage 2 and 3, bilateral Class II molar and canine relationships, good-quality lateral cephalograms, little or no crowding.

Exclusion criteria: Chronic medication, a history of pharyngeal soft tissue surgery, congenital craniofacial deformities, a history of orthodontic treatment or functional appliance treatment and patients who do not use their appliance regularly (15-24 hours/day) in the treatment follow-up form.

The minimum required sample size was identified as 60 individuals based on the power analysis (alpha error probability=0.05) that was conducted using the G*Power 3.1 software. The sample was comprised of a total of 72 patients at the ages of 10 to 13, including 32 males and 40 females. The TWB group consisted of 36 patients (22 females, 14 males, mean age: 11.9±1.5) and The MB group consisted of 36 patients (18 females, 18 males, mean age: 11.8 ±1.2) (Table 1). Patients were divided into groups according to their registration numbers, odd numbered MB, even numbered TWB.

Mandibular advancement was performed until an edge-to-edge incisor bite in sagittal with a 2-3-mm bite opening in vertical was achieved during vax bite registration. The patients were instructed to wear the appliance 15-24 hours/day. The patients were followed up every four weeks, and the treatment was ended when the overjet and overbite was reduced to 1-2 mm. A lateral cephalometric image was taken from each patient in the session where the appliance was placed for the beginning of treatment (T0). The patient follow-ups were made monthly throughout the treatment, and the second lateral cephalogram was taken when a class I canine relationship was achieved (T1). The mean duration of the treatment was about 12 months.

The cephalometric radiographs were evaluated by the same researcher (G.P.) for each patient. Lateral cephalometric films were obtained with Planmeca 2011-05 Proline Pan / Ceph X-Ray X-ray machine (Planmeca, Helsinki, Finland). All participants were positioned in the cephalostat with the sagittal plane at a right angle to the X-ray path, the Frankfort plane parallel to the ground plane, the teeth in centric occlusion, and the lips in the rest position. The all patients were asked not to swallow. The linear and angular measurements were evaluated with Facad trial version (Ilexis AB, Linkoping, Sweden) as shown in Figure 1. Thirty cephalometric radiographs were randomly selected and re-evaluated after four weeks. The intra-class correlation coefficients for measurements were > 0.990.

Statistical analysis

The IBM SPSS Statistics 22 program was used for the statistical analyses of the results. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test the normality of the distributions of the data, and it was found that the data were not normally distributed. In the analyses, descriptive statistics (mean, standard deviation, frequency), Mann-Whitney U test for the intergroup comparisons of the variables and Wilcoxon signed-rank test for the intragroup comparisons were used. The level of statistical significance was accepted as $p < 0.05$.

RESULTS

The study was carried out with a total of 72 patients at the ages of 10 to 13, including 32 male and 40 female patients. The mean age of the patients was 11.85±1.3 years (Table 1).

In the TWB and MB groups, the increases in the PNS-AD1 and AD1-Ba measurements from beginning of treatment (T0) to completion of treatment (T1) were statistically significant ($p < 0.05$). The mean PNS-AD2 measurements of the TWB group at T0 and T1 were significantly higher than those of the MB group ($p < 0.05$). The decrease in the mean Ptm-Ba measurement in the MB group from T0 to T1 was significant ($p < 0.05$) (Table 2).

In the TWB group, the decrease in the mean TGH measurement from T0 to T1 was significant ($p < 0.05$). The mean MPT measurements of the TWB group at T0 and T1 were significantly higher than those of the MB group ($p < 0.05$). In the TWB group, the increases in the IAS and C3H measurements from T0 to T1 were significant ($p < 0.05$). In the MB group, the decrease in the mean MPH measurement from T0 to T1 was significant ($p < 0.05$) (Table 2).

Table 1. Evaluations of appliance groups.

	Twin Block Mean±SD	Monoblock Mean±SD	p
Age $_{\text{Mean±SD}}$	11.9±1.5 (10)	11.8 ±1.2 (10)	[1]0.467
Gender $_{\text{n (\%)}}$			
Male	14 (31.3%)	18 (50%)	[2]0.203
Female	22 (68.2%)	18 (50%)	

[1]Mann Whitney U Test, [2]Continuity (yates) düzeltmesi

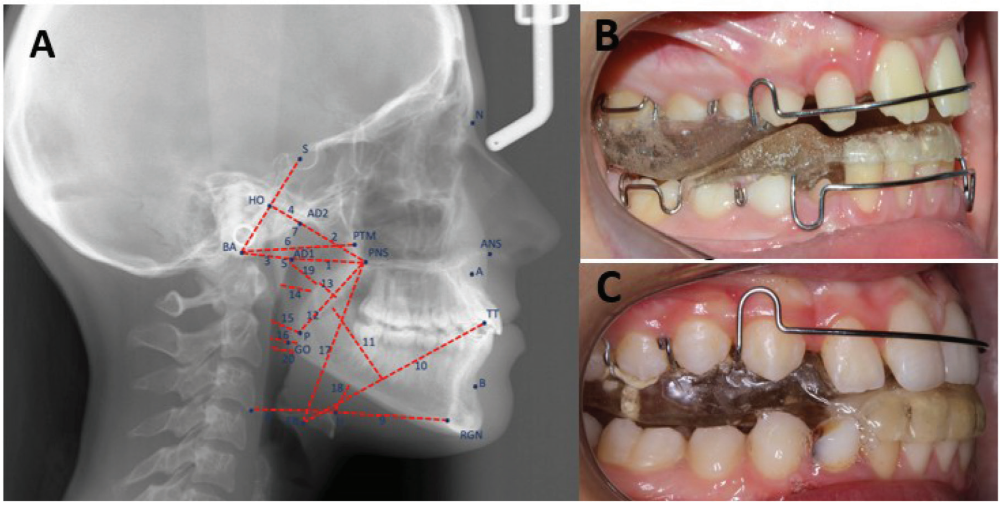

Figure 1. The linear and angular measurements evaluated with Facad trial version. **A)** Cephalometric landmarks, angular and linear measurements. Hyoidale (H): It is the uppermost and anterior point of the hyoid bone corpus. P: It is the most extreme point of the soft palate. EB: The base of the epiglottis is also the most posteroinferior point at the base of the tongue. TT: Tongue tip. RGN: It is the lowest and posterior point of the mandibular symphysis. C3: It is the lowest and anterior point of the third cervical vertebra. Hormiyon (HO): The point located at the intersection between the perpendicular line to Sella-Ba and the cranial base. AD1: It is the point where the line connecting the PNS and the Basion and the posterior of the nasopharyngeal wall intersect. AD2: It is the point where the line drawn from the PNS to the midpoint of the line connecting the Sella-Basion and the posterior of the nasopharyngeal wall intersect. 1. PNS-AD1: Lower airway thickness. The distance from PNS to posterior pharyngeal wall along the line from PNS to Ba 2.PNS-AD2: Upper airway thickness. The distance from PNS to the adenoid tissue (AD2) along the line from PNS to Hormion. 3. AD1-BA: Lower adenoid thickness. The distance from Ba to adenoid (AD1) along the line from PNS to Ba. 4. AD2-H: Upper adenoid thickness. The distance from AD2 to Ho. Upper adenoid thickness. 5. PNS-BA: The distance from PNS to Ba 6. PTM-BA: The distance from Ptm to Ba 7. PNS-H: Total upper airway thickness. The distance from PNS to H 8.C3H: Distance between hyoid and C3 9. HRGN: Distance between hyoid bone and RGN 10. TGL: Tongue length. Distance between Eb to Tt 11. TGH: Tongue height. It is the perpendicular distance descending from the tongue dorsum to the Ep-Tt plane 12.MAS: Middle airway space (width of airway along parallel line to Go- B line through P 13. IAS: Inferior airway space 14. SPAS: Superior posterior airway space 15. PNSP: Soft palate length 16.MPT: Softpalate thickness 17.VAL: Vertical airway length. Distance between PNS and Eb 18.MPH: Perpendicular distance from hyoid bone to mandibular plane 19. Mcnamara's Upper Pharynx Dimension: Minimum distance from the soft palate to the nearest point of the posterior pharyngeal Wall 20. Mcnamara's Lower Pharynx Dimension: Minimum distance from the point where the posterior tongue contour crosses the mandible to the nearest point on the pharyngeal Wall. **B)** Application of Twin block appliances. **C)** Application of Monoblock appliances.

In both groups, the decreases that were observed in the U1xL1, ANB and SNA measurements from T0 to T1 were significant ($p < 0.05$). The increases in the L1xNB, IMPA and FMA measurements in the TWB group from T0 to T1 were significant ($p < 0.05$). In both groups, the increases in the Go-Gn, ANS-Me and SNB measurements from T0 to T1 were significant ($p < 0.05$) (Table 2).

The amounts of increase in the IAS, L1xNB, IMPA and FMA measurements from T0 to T1 in the TWB group were significantly higher than those in the MB group ($p < 0.05$) (Table 3).

Table 2. Cephalometric and Pharyngeal Airway evaluation of appliance groups.

Groups		**Twin Block Mean±SD**	**Monoblock Mean±SD**	**[1]p**
PNS-AD1	T0	19.27±5.90 (21.2)	20.77±5.31 (22.7)	0.204
	T1	20.10±5.44 (21.9)	21.35±4.84 (23.0)	0.235
	[2]p	0.001*	0.033*	
AD1-Ba	T0	18.08±4.33 (16.7)	17.15±4.09 (17.3)	0.515
	T1	17.41±3.84 (16.9)	16.22±3.44 (16.2)	0.347
	[2]p	0.002*	0.001*	
PNS-AD2	T0	28.55±3.09 (27.6)	26.30±4.12 (26.9)	0.046*
	T1	28.52±3.25 (28.3)	26.37±4.15 (26.9)	0.048*
	[2]p	0.903	0.562	
AD2-H	T0	7.34±2.07 (7.6)	8.26±3.09 (8.4)	0.145
	T1	7.66±2.45 (7.8)	8.07±2.95 (8.4)	0.550
	[2]p	0.262	0.127	
PNS-Ba	T0	39.54±4.39 (38.7)	38.96±5.56 (40.4)	0.653
	T1	39.51±4.02 (39.6)	38.52±5.82 (39.8)	0.793
	[2]p	0.537	0.140	
Ptm-Ba	T0	37.44±3.69 (37.6)	37.37±6.05 (37.8)	0.614
	T1	37.40±3.76 (38.3)	36.98±6.25 (37.5)	0.952
	[2]p	0.575	0.018*	
PNS-H	T0	36.58±2.68 (37.2)	34.66±5.74 (35.4)	0.169
	T1	36.41±2.36 (36.9)	34.38±5.74 (34.9)	0.119
	[2]p	0.379	0.537	
Upper Pharynx	T0	10.16±1.80 (10.5)	9.85±2.54 (9.6)	0.643
	T1	10.41±2.00 (10.6)	10.14±2.67 (9.8)	0.532
	[2]p	0.134	0.274	
Lower Pharynx	T0	8.72±3.09 (8.4)	8.86±2.19 (8.6)	0.697
	T1	8.80±3.12 (8.3)	8.89±2.23 (8.5)	0.638
	[2]p	0.896	0.278	
TGL	T0	65.59±5.21 (64.8)	67.08±10.89 (68.9)	0.018*
	T1	65.88±4.91 (65.2)	66.45±10.33 (69.0)	0.071
	[2]p	0.881	0.094	
TGH	T0	30.84±5.32 (31.5)	34.10±11.31 (31.2)	0.372
	T1	29.98±4.71 (30.9)	33.65±11.32 (31.2)	0.219
	[2]p	0.007*	0.092	
PNSP	T0	31.18±2.91 (31.9)	29.42±7.20 (30.9)	0.888
	T1	31.62±2.53 (31.8)	29.65±7.19 (31.8)	0.586
	[2]p	0.421	0.489	
MPT	T0	5.01±0.79 (5.0)	4.43±1.04 (4.6)	0.008*
	T1	4.97±0.83 (5.1)	4.31±1.15 (4.5)	0.006*
	[2]p	0.340	0.166	
SPAS	T0	11.93±2.44 (11.7)	11.22±3.07 (11.6)	0.298
	T1	11.68±2.29 (11.6)	11.26±2.95 (12.1)	0.941
	[2]p	0.197	0.421	
MAS	T0	8.52±3.20 (8.4)	9.20±2.94 (8.8)	0.365
	T1	8.40±2.92 (8.6)	8.96±2.84 (9.0)	0.375
	[2]p	0.184	0.355	
IAS	T0	8.36±3.12 (7.5)	8.91±3.12 (9.1)	0.292
	T1	8.69±3.16 (7.7)	8.95±3.27 (8.9)	0.624
	[2]p	0.001*	0.822	
VAL	T0	55.97±6.60 (56.4)	56.89±10.53 (55.5)	0.464
	T1	56.34±6.33 (56.8)	57.26±10.40 (56.4)	0.586
	[2]p	0.513	0.837	
MPH	T0	8.86±4.18 (8.5)	10.16±4.86 (9.2)	0.224

	T1	8.75±3.57 (8.1)	8.99±3.72 (9.1)	0.653
	²p	0.197	0.006*	
C3H	T0	30.51±3.61 (30.2)	31.16±6.26 (31.2)	0.337
	T1	31.12±3.54 (31.4)	30.65±6.01 (30.8)	0.506
	²p	0.015*	0.736	
HRGN	T0	31.78±4.51 (31.4)	32.48±6.78 (33)	0.317
	T1	31.88±4.52 (32.5)	31.69±6.67 (33)	0.577
	²p	0.852	0.073	
SNA	T0	82.19±3.90 (82.0)	79.91±3.16 (80.0)	0.022*
	T1	81.09±4.17 (80.0)	78.00±4.11 (77.0)	0.006*
	²p	0.004*	0.001*	
SNB	T0	74.91±3.74 (75.0)	73.72±3.45 (73.0)	0.185
	T1	77.03±4.12 (78.0)	75.22±3.69 (75.0)	0.068
	²p	0.001*	0.001*	
ANB	T0	7.28±1.57 (8.0)	6.19±1.38 (6.0)	0.003*
	T1	4.00±1.57 (4.0)	3.41±1.21 (4.0)	0.137
	²p	0.001*	0.001*	
U1 x L1	T0	108.94±6.56 (109.5)	108.19±7.27 (110.0)	0.527
	T1	106.28±5.98 (106.5)	105.91±6.24 (108.0)	0.706
	²p	0.001*	0.001*	
U1 x NA	T0	23.75±5.46 (23.0)	25.78±4.40 (25.5)	0.035*
	T1	22.31±6.01 (20.5)	24.69±4.84 (24.5)	0.076
	²p	0.082	0.062	
L1 X NB	T0	28.31±6.31 (30.0)	28.22±7.31 (29.0)	0.893
	T1	31.13±5.50 (32.0)	28.91±6.18 (28.0)	0.116
	²p	0.001*	0.205	
IMPA	T0	98.72±6.63 (100.0)	98.59±8.64 (101.0)	0.742
	T1	101.56±6.41 (102.0)	99.03±6.17 (100.0)	0.166
	²p	0.001*	0.489	
FMA	T0	25.69±4.91 (26.0)	26.06±4.48 (25.0)	0.984
	T1	27.47±4.96 (28.0)	26.31±3.60 (26.0)	0.424
	²p	0.004*	0.616	
Saddle	T0	125.41±4.36 (126.5)	125.66±6.20 (126.0)	0.840
	T1	126.28±5.54 (128.5)	126.47±6.88 (126.5)	1.000
	²p	0.107	0.119	
Articulare	T0	140.88±7.64 (140.0)	142.53±7.29 (142.0)	0.480
	T1	141.56±6.84 (140.0)	141.44±8.04 (141.5)	0.909
	²p	0.827	0.083	
Gonial	T0	128.28±5.80 (128.5)	126.94±5.93 (127.0)	0.296
	T1	127.78±6.38 (128.0)	127.25±6.28 (128.0)	0.957
	²p	0.144	0.587	
Co-A	T0	79.00±8.20 (82.0)	78.09±6.18 (80.0)	0.331
	T1	79.66±7.25 (80.0)	78.75±5.67 (79.5)	0.269
	²p	0.567	0.423	
Co-Gn	T0	92.94±10.35 (95.5)	92.59±7.43 (95.5)	0.415
	T1	96.34±11.32 (95.0)	95.78±7.42 (95.0)	0.710
	²p	0.004*	0.001*	
ANS-Me	T0	54.94±4.43 (54.0)	56.34±4.06 (57.0)	0.236
	T1	56.88±5.05 (55.0)	58.16±4.50 (59.0)	0.251
	²p	0.001*	0.001*	

¹Mann Whitney U Test, ²Wilcoxon sign test, *$p < 0.05$

Table 3. Evaluation of appliance groups in terms of T1 changes according to T0 time.

T0-T1 differences	Twin Block Mean±SD	Monoblock Mean±SD	p
PNS-AD1	0.83±1.41 (0.7)	0.58±1.35 (0.7)	0.819
AD1-Ba	-0.67±1.21 (-1.1)	-0.93±1.23 (-0.9)	0.742
PNS-AD2	-0.03±1.37 (0.6)	0.08±1.34 (0.5)	0.732
AD2-H	0.31±1.18 (-0.1)	-0.19±0.91 (-0.2)	0.181
PNS-Ba	-0.03±1.52 (-0.5)	-0.44±1.30 (-0.2)	0.783
Ptm-Ba	-0.04±1.09 (-0.2)	-0.39±1.17 (-0.3)	0.131
PNS-H	-0.17±1.00 (-0.7)	-0.27±1.46 (0.1)	0.783
Upper Pharynx	0.25±0.61 (0.0)	0.30±1.21 (0.1)	0.888
Lower Pharynx	0.08±0.54 (-0.2)	0.03±0.93 (-0.1)	0.436
TGL	0.29±2.38 (-0.6)	-0.63±1.95 (-1.2)	0.127
TGH	-0.86±1.91 (-0.7)	-0.45±1.47 (-0.4)	0.481
PNSP	0.44±1.53 (-0.2)	0.23±1.48 (-0.3)	0.432
MPT	-0.04±0.39 (-0.1)	-0.12±0.56 (-0.1)	0.768
SPAS	-0.25±0.94 (-0.4)	0.04±1.65 (-0.5)	0.643
MAS	-0.12±0.68 (-0.2)	-0.23±1.17 (-0.1)	0.861
IAS	0.32±0.42 (0.2)	0.03±0.82 (0.1)	**0.032***
VAL	0.37±2.62 (-0.3)	0.36±2.06 (-0.3)	0.904
MPH	-0.11±2.20 (-0.5)	-1.17±2.57 (-0.4)	0.452
C3H	0.61±1.87 (1.0)	-0.51±2.27 (0.6)	0.057
HRGN	0.10±1.92 (-0.6)	-0.79±3.13 (-0.8)	0.190
SNA	-1.09±1.92 (-1.0)	-1.91±2.61 (-1.0)	0.226
SNB	2.13±1.58 (2.0)	1.50±1.68 (1.5)	0.087
ANB	-3.28±1.08 (-3.0)	-2.78±0.94 (-3.0)	0.068
U1 x L1	-2.66±1.23 (-2.5)	-2.28±1.84 (-2.0)	0.591
U1 x NA	-1.44±4.01 (-3.0)	-1.09±3.02 (-1.0)	0.571
L1 X NB	2.81±2.60 (3.0)	0.69±4.51 (1.5)	**0.048***
IMPA	2.84±2.85 (3.0)	0.44±5.27 (2.0)	**0.032***
FMA	1.78±2.97 (2.5)	0.25±2.95 (0.0)	**0.045***
Saddle	0.88±3.14 (1.5)	0.81±3.47 (2.0)	0.839
Articulare	0.69±4.38 (-0.5)	-1.09±3.11 (-1.0)	0.351
Gonial	-0.50±3.05 (-1.0)	0.31±2.97 (1.0)	0.228
Co-A	0.66±5.89 (2.0)	0.66±3.86 (0.5)	0.946
Co-Gn	3.41±5.70 (3.0)	3.19±4.28 (3.5)	0.627
ANS-Me	1.94±1.72 (2.0)	1.81±2.63 (1.5)	0.754

Mann Whitney U test, *$p < 0.05$

In the TWB group
The amounts of the increase in the MPT, C3H, Co-A and Co-Gn measurements from T0 to T1 in the female patients were significantly higher than those in the male patients ($p < 0.05$). The amount of decrease in the U1xL1 measurements from T0 to T1 in the female patients was significantly higher than that in the male patients ($p < 0.05$). The amount of increase in the L1xNB measurements from T0 to T1 in the male patients was significantly higher than that in the female patients ($p < 0.05$) (Table 4).

In the MB group
The amounts of increase in the AD2-H and VAL

Table 4. Evaluation of separate genders in appliance groups in terms of T1 changes according to T0 time.

T0-T1 differences	Twin Block Male Mean±SD	Twin Block Female Mean±SD	p	Monoblock Male Mean±SD	Monoblock Female Mean±SD	p
PNS-AD1	1.07±0.87 (0.8)	0.72±1.60 (0.6)	0.222	0.60±1.04 (1.0)	0.56±1.65 (0.6)	0.651
AD1-Ba	-0.86±1.08 (-1.2)	-0.58±1.27 (-1.1)	0.515	-0.74±0.8 (-0.7)	-1.11±1.56 (-0.9)	0.611
PNS-AD2	0.65±0.68 (0.8)	-0.34±1.51 (-0.1)	0.080	0.65±0.94 (0.6)	-0.5±1.46 (-0.9)	0.065
AD2-H	0.01±1.14 (-0.4)	0.45±1.19 (0.8)	0.639	-0.39±0.6 (-0.5)	0.02±1.12 (0.0)	**0.032***
PNS-Ba	-0.73±1.13 (-0.6)	0.29±1.59 (-0.5)	0.207	-0.51±1.06 (-0.2)	-0.37±1.53 (-0.1)	0.850
Ptm-Ba	-0.18±0.96 (-0.2)	0.02±1.16 (-0.2)	0.501	-0.39±1.10 (-0.2)	-0.39±1.27 (-0.4)	0.777
PNS-H	-0.06±0.91 (-0.4)	-0.22±1.05 (-0.7)	0.392	-0.01±1.15 (0.1)	-0.54±1.71 (-0.1)	0.910
Upper Pharynx	0.07±0.39 (-0.1)	0.33±0.68 (0.1)	0.271	0.11±0.74 (0.0)	0.48±1.55 (0.1)	0.200
Lower Pharynx	-0.13±0.4 (-0.3)	0.17±0.58 (0.0)	0.107	-0.15±0.69 (-0.2)	0.21±1.11 (-0.1)	0.521
TGL	-0.50±1.19 (-0.8)	0.64±2.71 (-0.2)	0.381	-1.08±1.49 (-1.2)	-0.19±2.28 (0.2)	0.274
TGH	-0.39±0.94 (-0.6)	-1.07±2.20 (-0.7)	0.464	-0.66±0.97 (-0.4)	-0.24±1.86 (-0.1)	0.346
PNSP	0.16±0.58 (0.0)	0.57±1.80 (-0.3)	0.596	0.76±1.21 (0.4)	-0.31±1.57 (-0.7)	**0.017***
MPT	-0.25±0.34 (-0.3)	0.05±0.38 (-0.1)	**0.046***	0.07±0.42 (0.0)	-0.31±0.64 (-0.2)	0.097
SPAS	-0.49±0.89 (-0.7)	-0.14±0.96 (-0.4)	0.207	-0.10±1.08 (-0.5)	0.18±2.11 (0.0)	0.821
MAS	-0.29±0.79 (-0.4)	-0.04±0.63 (-0.2)	0.370	0.13±0.97 (-0.1)	-0.59±1.27 (-0.3)	0.346
IAS	0.47±0.45 (0.3)	0.26±0.40 (0.2)	0.238	0.33±0.53 (0.2)	-0.26±0.95 (-0.5)	**0.005***
VAL	0.31±2.95 (-0.4)	0.40±2.53 (-0.3)	0.415	-0.50±1.45 (-0.5)	1.23±2.26 (0.6)	**0.036***
MPH	0.01±2.59 (-0.5)	-0.17±2.07 (-0.4)	0.611	-0.82±1.94 (-0.3)	-1.52±3.09 (-1.0)	0.365
C3H	-0.18±1.66 (0.4)	0.96±1.88 (1.3)	**0.034***	0.49±1.37 (0.7)	-1.51±2.57 (-1.2)	**0.020***
HRGN	-0.21±1.9 (-0.8)	0.24±1.96 (-0.5)	0.597	-1.06±2.82 (-1.3)	-0.52±3.47 (-0.7)	0.624
SNA	-0.60±2.27 (-0.5)	-1.32±1.76 (-1.0)	0.338	-2.19±3.6 (-1.5)	-1.63±0.96 (-1.0)	0.893
SNB	2.50±1.18 (2.5)	1.95±1.73 (2.0)	0.546	1.69±1.96 (2.0)	1.31±1.40 (1.0)	0.392
ANB	-3.10±1.20 (-3.0)	-3.36±1.05 (-3.0)	0.459	-2.63±0.72 (-2.5)	-2.94±1.12 (-3.0)	0.421
U1 x L1	-2.10±1.20 (-2.0)	-2.91±1.19 (-3.0)	**0.029***	-1.50±1.97 (-2.0)	-3.06±1.34 (-3.0)	**0.009***
U1 x NA	-1.00±4.42 (-0.5)	-1.64±3.90 (-3.0)	0.774	-0.13±3.01 (-0.5)	-2.06±2.79 (-1.0)	0.115
L1 X NB	4.30±3.30 (5.0)	2.14±1.93 (2.0)	**0.005***	-0.13±5.76 (0.5)	1.50±2.73 (3.0)	0.448
IMPA	3.30±3.40 (4.0)	2.64±2.63 (2.0)	0.209	-1.13±6.02 (1.5)	2.00±3.98 (3.5)	0.095
FMA	2.30±2.06 (2.5)	1.55±3.32 (2.5)	0.524	-0.25±3.09 (-1.0)	0.75±2.82 (0.5)	0.294
Saddle	-0.30±3.37 (1.0)	1.41±2.95 (2.0)	0.187	0.44±4.11 (0.5)	1.19±2.76 (2.0)	0.718
Articulare	0.60±5.25 (-2.0)	0.73±4.06 (0.0)	0.550	-1.38±3.36 (-1.0)	-0.81±2.93 (-1.0)	0.894
Gonial	-0.80±3.01 (-2.0)	-0.36±3.13 (0.0)	0.933	0.56±2.92 (1.5)	0.06±3.09 (0.0)	0.718
Co-A	-2.10±4.51 (-1.5)	1.91±6.11 (3.0)	**0.049***	2.00±4.26 (2.5)	-0.69±2.96 (-1.0)	0.061
Co-Gn	0.40±3.81 (2.0)	4.77±5.96 (4.0)	**0.017***	4.69±4.90 (5.5)	1.69±3.00 (2.0)	**0.030***
ANS-Me	2.00±2.00 (2.5)	1.91±1.63 (2.0)	0.967	2.44±2.61 (2.5)	1.19±2.59 (1.0)	0.296

Mann Whitney U test, *p < 0.05

measurements from T0 to T1 in the female patients were significantly higher than those in the male patients ($p < 0.05$). The amount of decrease in the U1xL1 measurements from T0 to T1 in the female patients was significantly higher than that in the male patients ($p < 0.05$). The amounts of increase in the PNSP, IAS, C3H and Co-Gn measurements from T0 to T1 in the male patients were significantly higher than those in the female patients ($p < 0.05$) (Table 4).

In the male patients

The amounts of increase in the L1xNB, IMPA and FMA measurements from T0 to T1 in the TWB group were significantly higher than those in the MB group ($p < 0.05$). The amount of increase in the Co-Gn measurements from T0 to T1 in the MB group was significantly higher than that in the TWB group ($p < 0.05$) (Table 5).

In the female patients

The amounts of increase in the PNSP, IAS and C3H measurements from T0 to T1 in the TWB group were significantly higher than those in the MB group ($p < 0.05$) (Table 5).

Table 5. Evaluation of separate appliance groups in genders in terms of T1 changes according to T0 time.

T0-T1 differences	Male			Female		
	Twin Block Mean±SD	Monoblock Mean±SD	p	Twin Block Mean±SD	Monoblock Mean±SD	p
PNS-AD1	1.07±0.87 (0.8)	0.60±1.04 (1.0)	0.771	0.72±1.60 (0.6)	0.56±1.65 (0.6)	0.734
AD1-Ba	-0.86±1.08 (-1.2)	-0.74±0.80 (-0.7)	0.475	-0.58±1.27 (-1.1)	-1.11±1.56 (-0.9)	0.668
PNS-AD2	0.65±0.68 (0.8)	0.65±0.94 (0.6)	0.673	-0.34±1.51 (-0.1)	-0.50±1.46 (-0.9)	0.871
AD2-H	0.01±1.14 (-0.4)	-0.39±0.60 (-0.5)	0.187	0.45±1.19 (0.8)	0.02±1.12 (0.0)	0.564
PNS-Ba	-0.73±1.13 (-0.6)	-0.51±1.06 (-0.2)	0.369	0.29±1.59 (-0.5)	-0.37±1.53 (-0.1)	0.307
Ptm-Ba	-0.18±0.96 (-0.2)	-0.39±1.10 (-0.2)	0.711	0.02±1.16 (-0.2)	-0.39±1.27 (-0.4)	0.173
PNS-H	-0.06±0.91 (-0.4)	-0.01±1.15 (0.1)	0.916	-0.22±1.05 (-0.7)	-0.54±1.71 (-0.1)	0.941
Upper Pharynx	0.07±0.39 (-0.1)	0.11±0.74 (0.0)	0.958	0.33±0.68 (0.1)	0.48±1.55 (0.1)	0.525
Lower Pharynx	-0.13±0.40 (-0.3)	-0.15±0.69 (-0.2)	0.958	0.17±0.58 (0.0)	0.21±1.11 (-0.1)	0.604
TGL	-0.50±1.19 (-0.8)	-1.08±1.49 (-1.2)	0.187	0.64±2.71 (-0.2)	-0.19±2.28 (0.2)	0.399
TGH	-0.39±0.94 (-0.6)	-0.66±0.97 (-0.4)	0.958	-1.07±2.2 (-0.7)	-0.24±1.86 (-0.1)	0.322
PNSP	0.16±0.58 (0.0)	0.76±1.21 (0.4)	0.428	0.57±1.8 (-0.3)	-0.31±1.57 (-0.7)	**0.049***
MPT	-0.25±0.34 (-0.3)	0.07±0.42 (0.0)	0.113	0.05±0.38 (-0.1)	-0.31±0.64 (-0.2)	0.083
SPAS	-0.49±0.89 (-0.7)	-0.10±1.08 (-0.5)	0.342	-0.14±0.96 (-0.4)	0.18±2.11 (0.0)	0.965
MAS	-0.29±0.79 (-0.4)	0.13±0.97 (-0.1)	0.291	-0.04±0.63 (-0.2)	-0.59±1.27 (-0.3)	0.307
IAS	0.47±0.45 (0.3)	0.33±0.53 (0.2)	0.398	0.26±0.40 (0.2)	-0.26±0.95 (-0.5)	**0.001***
VAL	0.31±2.95 (-0.4)	-0.50±1.45 (-0.5)	0.673	0.40±2.53 (-0.3)	1.23±2.26 (0.6)	0.525
MPH	0.01±2.59 (-0.5)	-0.82±1.94 (-0.3)	0.526	-0.17±2.07 (-0.4)	-1.52±3.09 (-1.0)	0.198
C3H	-0.18±1.66 (0.4)	0.49±1.37 (0.7)	0.187	0.96±1.88 (1.3)	-1.51±2.57 (-1.2)	**0.004***
HRGN	-0.21±1.9 (-0.8)	-1.06±2.82 (-1.3)	0.493	0.24±1.96 (-0.5)	-0.52±3.47 (-0.7)	0.399
SNA	-0.60±2.27 (-0.5)	-2.19±3.60 (-1.5)	0.287	-1.32±1.76 (-1.0)	-1.63±0.96 (-1.0)	0.391
SNB	2.50±1.18 (2.5)	1.69±1.96 (2.0)	0.267	1.95±1.73 (2.0)	1.31±1.40 (1.0)	0.133
ANB	-3.10±1.20 (-3.0)	-2.63±0.72 (-2.5)	0.363	-3.36±1.05 (-3.0)	-2.94±1.12 (-3.0)	0.236
U1 x L1	-2.10±1.20 (-2.0)	-1.50±1.97 (-2.0)	0.777	-2.91±1.19 (-3.0)	-3.06±1.34 (-3.0)	0.591
U1 x NA	-1.00±4.42 (-0.5)	-0.13±3.01 (-0.5)	0.873	-1.64±3.90 (-3.0)	-2.06±2.79 (-1.0)	0.869
L1 X NB	4.30±3.30 (5.0)	-0.13±5.76 (0.5)	**0.034***	2.14±1.93 (2.0)	1.50±2.73 (3.0)	0.741
IMPA	3.30±3.40 (4.0)	-1.13±6.02 (1.5)	**0.010***	2.64±2.63 (2.0)	2.00±3.98 (3.5)	0.788
FMA	2.30±2.06 (2.5)	-0.25±3.09 (-1.0)	**0.045***	1.55±3.32 (2.5)	0.75±2.82 (0.5)	0.427
Saddle	-0.30±3.37 (1.0)	0.44±4.11 (0.5)	0.411	1.41±2.95 (2.0)	1.19±2.76 (2.0)	0.799
Articulare	0.60±5.25 (-2.0)	-1.38±3.36 (-1.0)	0.916	0.73±4.06 (0.0)	-0.81±2.93 (-1.0)	0.347
Gonial	-0.80±3.01 (-2.0)	0.56±2.92 (1.5)	0.288	-0.36±3.13 (0.0)	0.06±3.09 (0.0)	0.432
Co-A	-2.10±4.51 (-1.5)	2±4.26 (2.5)	0.063	1.91±6.11 (3.0)	-0.69±2.96 (-1.0)	0.105
Co-Gn	0.40±3.81 (2.0)	4.69±4.9 (5.5)	**0.011***	4.77±5.96 (4.0)	1.69±3.00 (2.0)	0.079
ANS-Me	2.00±2.00 (2.5)	2.44±2.61 (2.5)	0.766	1.91±1.63 (2.0)	1.19±2.59 (1.0)	0.315

Mann Whitney U test, *p < 0.05

DISCUSSION

Class II malocclusion is one of the most prevalent types of malocclusions, and it is frequently associated with airway problems.[15] In cases of mandibular retrognathia where growth and development are still going on, the ideal mandible-maxilla relationships are targeted in orthopedic treatments by the anterior positioning of the mandible. With this movement of the mandible, the pharyngeal airway is also affected via the hyoid bone, tongue and associated muscles, which are a part of the upper respiratory system.[6,16] Lateral cephalometric is frequently preferred not only due to their advantages such as their easy accessibility, low cost and low radiation dose but also for the fact that they provide adequate and accurate data in the examinations of the oropharyngeal airway.[17]

Pharyngeal airway changes following orthodontic treatments have been the subject of many studies that involved functional Class II treatments. In their study that investigated the effects of activators on the oropharyngeal airway in patients around the age of 10, Cortese et al.[18] found no significant difference in any of the upper, middle or lower airways in this process between treatment and control groups. Restrepo et al.[6] examined the effects of activator and bionator appliances on the oropharyngeal airway in 6-8-year-old children and found significant differences in the AD1 and AD2 measurements, where this region is a region that is associated with adenoids. Another study reported increases in almost all measurements in the Frankel-2, Trainer, X-bow and control groups, while only the increases in the PNS-AD2 and MAS levels in Frankel-2 were significant.[19] The authors determined the effectiveness of these fixed and removable appliances to be the same in terms of nasopharyngeal and oropharyngeal airway changes. It is also important to note that the ages of the patients in their study were young (8-10 y.o.), and their growth and development were at the active stage.

Alhammadi et al.[20] used CBCT to compare the TWB (age:11) and Forsus (age:13) groups to the control group (age:13). They found that nasopharyngeal airway volume increased in the TWB group and decreased in the other groups, the oropharyngeal airway volume in the TWB group was approximately 9 times higher in comparison to the control group. Pavoni et al.[21] compared bionator and activator appliances in individuals with a mean age between 9 and 10. In both groups, they found significant increases in the PNS-AD1 and PNS-AD2 measurements with significant decrease in the AD2-H measurements, and no significant change in the other measurements. Jena et al.[22] reported that after TWB treatment, the length and inclination of the soft palate decreased, while the thicknesses of the soft palate and retropalatal oropharynx increased. Another study revealed that the lower depth of the oropharynx decreased with the forward movement of the tongue after the use of a functional appliance.[23] Some studies reported changes in the position of the hyoid bone at the retention stage despite no change at the treatment stage following activator treatment.[24,25]

In our study, while the vast majority of the airway measurements showed an increase in both groups, the number of the parameters that increased was higher in the MB group. The increase in the lower airway was significant only in the TWB group, and the difference between the two groups was significant only regarding this parameter among all others. The middle airway was the only airway measurement that decreased in both groups. Considering the changes in soft tissues, the lower adenoid thickness in both groups decreased significantly. While tongue length increased in the TWB group and decreased in the MB group, tongue thickness decreased in both groups, where this change was significant only in the TWB group. Soft palate length increased in both groups, whereas soft palate thickness decreased in both groups. The movement of the hyoid bone was highly different between the two groups, where the movement in the sagittal direction was significantly more pronounced in the TWB group. In this movement of the hyoid bone, the effects of multiple factors such as the tongue, associated muscles, mandibular movements and rotations should be considered.[16] As this movement is influenced greatly by adenoid involution in the preadolescence and early periods, the effects of functional appliances on nasopharyngeal region changes may differ from study to study.[26] Another reason for the differences in the data of different studies is that the age groups of their participants were different. While the development speed of adenoid and nasopharyngeal tissues has been reported differently in many studies in many age ranges, the first 10 years of life and adolescence are the ages with the highest levels of changes.[27,28]

In cases with Class II anomalies accompanied by mandibular retrognathia who are in their growth and development period, the MB and TWB appliances are preferred frequently as they are economical, they can be easily removed and placed by the patient, and the outcomes they provide are successful.[29] In a study that compared MB and TWB treatments,[30] while the Co-ANS value increased in all groups, the minimum increase was in the TWB group. The effective mandibular length (Co-Gn) increased significantly only in the treatment groups. There was no significant difference between all groups in terms of their lower face height. Moreover, the increase in the proclination of the mandibular incisors was significant only in the TWB group. Another study comparing the X-Bow (10.58±1.27 y.o.), Frankel-2 (8.94±1.28 y.o.) and trainer (8.79±0.72 y.o.) appliances,[19] no significant change was seen in the sagittal development of the mandible. The retroclination of the maxillary incisors was significantly higher in the Frankel group than the X-Bow group, whereas the proclination of the mandibular incisors was 3 times higher in X-Bow than the other groups.

Baccaglione et al. compared activator and TWB and reported higher amounts of SNB increase, Co-Gn increase, maxillary incisor retroclination and mandibular incisor proclination in the activator group.[31] While both appliances had the same level of effectiveness in terms of their SNA values, no significant intergroup difference was identified in any parameter. In a study conducted with female patients at the age of 11,[32] the TWB appliance was reported to be more effective in the forward movement of the mandible, fixing of the molar relationship and overjet and maxillary incisor retroclination. The bionator appliance in the same study was more effective on mandibular incisor proclination, but the difference was not statistically significant. Another study examining the MB and TWB appliances in patients at the age of 12,[33] upper and lower incisors were affected by the appliance type and division 1/2. Additionally, it was reported that the mandibular incisor protrusion values in all groups were the highest in the individuals with Cl2/div1. In the study in which they compared the effects of the MB and TWB appliances.

The data in our study were in agreement with those in previous studies. In our study, both appliances were significantly effective in the reduction of the SNA and ANB angles and the increase in the SNB angle, while they were not significantly different from each other. Similarly, both appliances had the same effect in terms of the changes in the effective midface heights and mandibular lengths. While the vertical dimensions in both groups increased at similar rates, the FMA angle significantly increased only in the TWB group, there was a significant difference between the two groups in this respect, and this significant rotation of the mandible probably played a role in the change in the hyoid bone between the two groups. While no significant changes were observed in the maxillary incisors, the mandibular incisors in the TWB group were significantly more proclined than those in the MB group. While a likely reason for this result may be sex or division differences, another reason may be the different angles of the forces applied during the retention phase in the TWB group.

In a study used Herbst appliance (13.3±1.1 y.o.),[25] the highest increase in the upper airway depth after the treatment was in the hypopharynx in the male patients and in the retroglossal oropharynx in the female patients. Nonetheless, no significant difference was found between the male and female patients regarding nasopharyngeal depth. The hyoid bone moved downward to a significantly higher extent in the males and in comparison, to normal growth, a higher increase in hypopharyngeal depth was seen only in the males. Mislik et al. and Hanggi et al. reported in their study on individuals over the age of 9 that there was no sex difference in terms of oropharyngeal depth.[34,35] A study that looked at the relationship between skeletal patterns and pharyngeal airways in individuals aged 13 to 20 using CBCT images[36] determined airway volumes, except for the nasopharynx, to be higher in the males than the females.

In our study, an interesting finding was that while the appliance type had a significant effect on the cephalometric dental and hard tissue parameters in the male patients, it had a significant effect on the airway measurements in the female patients. The TWB appliance had a positive influence on the soft palate length, lower airway space and the anterior movement of the hyoid bone in the female patients, whereas it had a positive influence on the increase in the angles of the mandibular incisors and the rotation of the mandible in the male patients. The MB appliance was significantly more influential on the increase in the effective mandibular length (Co-Gn) in the male sex. Regarding the effects of the appliances based on the sexes, while the effects of sex on the airway-related measurements were much higher in MB than TWB, these effects on the cephalometric hard tissue and dental effects were more pronounced in TWB than MB.

CONCLUSION

Both MB and TWB appliances increase the pharyngeal airway dimensions, and the lower airway is most affected by the appliance type. The effects of the MB and TWB appliances on tongue dimensions and hyoid bone movements are different. Both MB and TWB appliances show similar effects in the correction of Class II malocclusions, but their effects on the rotation of the mandible and the inclination of the mandibular incisors are different. The effects of functional appliance treatment on the pharyngeal airway dimensions and dentoskeletal changes display differences based on appliance type and gender.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. Cremonini F, Cervinara F, Siciliani G, Lombardo L. Class II treatment in growing patients: Preliminary evaluation of the skeletal and dental effects of a new clear functional appliance. Appl Sci. 2022; 12(11):562.
2. Giuntini V, Vangelisti A, Masucci C, Defraia E, McNamara JA Jr, Franchi L. Treatment effects produced by the Twin-block appliance vs the Forsus Fatigue Resistant Device in growing Class II patients. Angle Orthod. 2015; 85(5):784-9.
3. Robin P. Observation sur un nouvel appareil de redressement. Rev Stomatol. 1902; 9:423-32.
4. Khoja A, Fida M, Shaikh A. Cephalometric evaluation of the effects of the Twin Block appliance in subjects with Class II, Division 1 malocclusion amongst different cervical vertebral maturation stages. Dental Press J Orthod. 2016; 21(3):73-84.

5. Manni A, Pasini M, Giuca MR, Morganti R, Cozzani M. A retrospective cephalometric study on pharyngeal airway space changes after rapid palatal expansion and Herbst appliance with or without skeletal anchorage. Prog Orthod. 2016; 17(1):29.
6. Awuapara S, Liñan C, Solis G, Meneses A, Lagravère M. Evaluation of the nasal septum and depth of palatal arch in different facial vertical patterns: A cone-beam computed tomography study. Int Orthod. 2021;1 9(2):228-34.
7. Abdalla Y, Brown L, Sonnesen L. Effects of rapid maxillary expansion on upper airway volume: A three-dimensional cone-beam computed tomography study. Angle Orthod. 2019; 89(6):917-23.
8. Kim KB. How has our interest in the airway changed over 100 years? Am J Orthod Dentofacial Orthop. 2015; 148(5):740-7.
9. Kannan A, Sathyanarayana HP, Padmanabhan S. Effect of functional appliances on the airway dimensions in patients with skeletal class II malocclusion: A systematic review. J Orthod Sci. 2017; 6(2):54-64.
10. El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: A CBCT study. Angle Orthod. 2014; 84(2):265-73.
11. Shete CS, Bhad WA. Three-dimensional upper airway changes with mandibular advancement device in patients with obstructive sleep apnea. Am J Orthod Dentofacial Orthop. 2017; 151(5):941-8.
12. Kochel J, Meyer-Marcotty P, Sickel F, Lindorf H, Stellzig-Eisenhauer A. Short-term pharyngeal airway changes after mandibular advancement surgery in adult Class II-Patients--a three-dimensional retrospective study. J Orofac Orthop. 2013; 74(2):137-52.
13. Hourfar J, Lisson JA, Kinzinger GSM. Changes of epiglottis and hyoid bone position after orthodontic treatment with cast splint fixed functional appliances. Clin Oral Investig. 2021; 25(3):1525-34.
14. Jena AK, Singh SP, Utreja AK. Effectiveness of twin-block and Mandibular Protraction Appliance-IV in the improvement of pharyngeal airway passage dimensions in Class II malocclusion subjects with a retrognathic mandible. Angle Orthod. 2013; 83(4):728-34.
15. Wishney M, Darendeliler MA, Dalci O. Myofunctional therapy and prefabricated functional appliances: An overview of the history and evidence. Aust Dent J. 2019; 64(2):135-44.
16. Li L, Liu H, Cheng H, Han Y, Wang C, Chen Y, Song J, Liu D. CBCT evaluation of the upper airway morphological changes in growing patients of class II division 1 malocclusion with mandibular retrusion using twin block appliance: A comparative research. PLoS One. 2014; 9(4):e94378.
17. Ansar J, Maheshwari S, Verma SK, Singh RK, Agarwal DK, Bhattacharya P. Soft tissue airway dimensions and craniocervical posture in subjects with different growth patterns. Angle Orthod. 2015; 85(4):604-10.
18. Cortese M, Pigato G, Casiraghi G, Ferrari M, Bianco E, Maddalone M. Evaluation of the oropharyngeal airway space in class II malocclusion treated with mandibular activator: A retrospective study. J Contemp Dent Pract. 2020; 21(6):666-72.
19. Atik E, Gorucu Coskuner H, Kocadereli I. 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. Aust Orthod J. 2017; 33(1):3-13.
20. Alhammadi MS, Almashraqi AA, Halboub E, Almahdi S, Jali T, Atafi A, Alomar F. Pharyngeal airway spaces in different skeletal malocclusions: A CBCT 3D assessment. Cranio. 2021; 39(2):97-106.
21. Pavoni C, Cretella Lombardo E, Franchi L, Lione R, Cozza P. Treatment and post-treatment effects of functional therapy on the sagittal pharyngeal dimensions in Class II subjects. Int J Pediatr Otorhinolaryngol. 2017; 101:47-50.
22. Ganesh G, Tripathi T. Effect of fixed functional appliances on pharyngeal airway dimensions in Skeletal Class II individuals - A scoping review. J Oral Biol Craniofac Res. 2021; 11(4):511-23.
23. Erbas B, Kocadereli I. Upper airway changes after Xbow appliance therapy evaluated with cone beam computed tomography. Angle Orthod. 2014; 84(4):693-700.
24. Ulusoy C, Canigur Bavbek N, Tuncer BB, Tuncer C, Turkoz C, Gencturk Z. Evaluation of airway dimensions and changes in hyoid bone position following class II functional therapy with activator. Acta Odontol Scand. 2014; 72(8):917-25.
25. Gu M, Lin Y, McGrath CP, Hägg U, Wong RW, Yang Y. Evaluation of the upper airway dimensions following Herbst appliance treatment in adolescents: A retrospective study. APOS Trends Orthod 2020; 10(3):153-63.
26. Uslu-Akcam O. Pharyngeal airway dimensions in skeletal class II: A cephalometric growth study. Imaging Sci Dent. 2017; 47(1):1-9.
27. Khyati N, Desai AL, Nambiar S, Natarajan S, Shetty S. Correlation of mandibular incisor inclination to marginal bone levels and cortical bone thickness in different skeletal patterns: A retrospective, cone beam computed tomography study. World J Dent. 2018; 9(4):291-6.
28. Kim YJ, Hong JS, Hwang YI, Park YH. Three-dimensional analysis of pharyngeal airway in preadolescent children with different anteroposterior skeletal patterns. Am J Orthod Dentofacial Orthop. 2010; 137(3):306.e1-11.
29. Idris G, Hajeer MY, Al-Jundi A. Soft- and hard-tissue changes following treatment of Class II

division 1 malocclusion with Activator versus Trainer: A randomized controlled trial. Eur J Orthod. 2019; 41(1):21-8.
30. Cesur E, Bayrak S, Kursun-Çakmak EŞ, Arslan C, Köklü A, Orhan K. Evaluating the effects of functional orthodontic treatment on mandibular osseous structure using fractal dimension analysis of dental panoramic radiographs. Angle Orthod. 2020; 90(6):783-93.
31. Baccaglione G, Rota E, Ferrari M, Maddalone M. Second class functional treatment: Andreasen Activator vs Twin Block. Int J Clin Pediatr Dent. 2020; 13(2):144-9.
32. Koretsi V, Zymperdikas VF, Papageorgiou SN, Papadopoulos MA. Treatment effects of removable functional appliances in patients with Class II malocclusion: A systematic review and meta-analysis. Eur J Orthod. 2015; 37(4):418-34.
33. Toran FD, Bolat E. Comparison of the effects of Monoblock And Twin Block Appliances in class II division 1 and class II division 2 patients. Süleyman Demirel Üniversitesi J Health Sci. 2020; 11(3):311-21.
34. Mislik B, Hänggi MP, Signorelli L, Peltomäki TA, Patcas R. Pharyngeal airway dimensions: A cephalometric, growth-study-based analysis of physiological variations in children aged 6-17. Eur J Orthod. 2014; 36(3):331-9.
35. Behrents RG, Shelgikar AV, Conley RS, Flores-Mir C, Hans M, Levine M, McNamara JA, Palomo JM, Pliska B, Stockstill JW, Wise J, Murphy S, Nagel NJ, Hittner J. Obstructive sleep apnea and orthodontics: An American Association of Orthodontists White Paper. Am J Orthod Dentofacial Orthop. 2019; 156(1):13-28.e1.
36. Claudino LV, Mattos CT, Ruellas AC, Sant' Anna EF. Pharyngeal airway characterization in adolescents related to facial skeletal pattern: A preliminary study. Am J Orthod Dentofacial Orthop. 2013; 143(6):799-809.

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