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Original Article

Conventional Twin-Block Versus Cervical Headgear and Twin-Block Combination: Therapeutic Effects on the Craniofacial Structures in Growing Subjects

Beytullah Gülsoy[1], Mehmet Ali Yavan[2]

[1]Private Orthodontist, İstanbul, Turkey
[2]Adıyaman University Faculty of Dentistry, Department of Orthodontics, Adıyaman, Turkey

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Main Points

- The cervical headgear twin-block combination was more effective in limiting maxillary development in the sagittal direction, but the side effects of upper incisor retroclination were found to be greater in this appliance.
- The conventional twin-block appliance was more effective in mandibular movement in the sagittal direction, but the lower incisor proclination side effects were found to be greater in this appliance.
- No significant difference was found between the two appliances in terms of their effects on maxillary and mandibular soft tissues.

Objective: To compare the short-term effects of the conventional twin-block (TB) appliance and the cervical headgear TB (CHG-TB) appliance on craniofacial structures.

Methods: The retrospective controlled study examined lateral cephalograms taken from 46 growing subjects. Individuals were divided into two groups according to the treatment. Group I consisted of 15 individuals (9 girls, 6 boys, mean age: 12.34±1.23 years) treated with the TB appliance and Group II consisted of 16 individuals (9 girls, 7 boys) treated with the CHG-TB appliance (mean age: 12.50±1.30 years). To distinguish the treatment effects of these appliances on growth, a control group of 15 untreated individuals (9 girls, 6 boys, mean age: 11.82±1.16 years) was included from the archives.

Results: Significant improvements were found in the interdental and maxillo-mandibular measurements in the treatment groups ($p<0.001$). Significant differences were observed in the SNA, SN/PP, and SN/GoGn values in the CHG-TB group compared to other groups ($p<0.05$). The mandible showed a significant downward movement in both treatment groups compared with the control group ($p<0.001$), while the change in SNB angle was statistically significant only in the TB group compared to the control group ($p<0.05$). Lower incisors showed significant proclination only in the TB group ($p<0.05$).

Conclusion: The CHG-TB appliance was found to be more effective in limiting maxillary growth and preventing lower incisor proclination compared with the TB appliance, whereas the TB appliance was more effective in anterior mandibular movement.

Keywords: Cephalometry, Cervical headgear, Class II malocclusion, Twin-Block

INTRODUCTION

Class II malocclusion are the anomalies most frequently encountered and treated by orthodontists.[1] Although functional appliances are viable treatment options for many malocclusion, they are mostly used for treating Class II Division 1 malocclusion caused by mandibular retrognathia.[2] Among functional appliances, the twin-block (TB) appliance is frequently used due to patient comfort, good patient cooperation, partial effect on speech, lower risk of aesthetic problems, and clinically significant skeletal and dental effects.[3] Nevertheless, functional appliances such as TB cause undesirable outcomes such as mandibular incisor protrusion and maxillary incisor

Corresponding author: Mehmet Ali Yavan, e-mail: yavanmehmetali@gmail.com

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retrusion.[4] To eliminate such adversities, various modifications have been tried on functional appliances in numerous studies.[5-7]

The literature indicates that the primary reason for attaching extraoral traction to functional appliances is to prevent antero-inferior maxillary growth.[8-10] In 1975, functional appliances were first combined with extraoral traction by Pfeiffer and Grobéty.[11] Based on the results obtained with this method, the authors indicated that the dentoalveolar development was affected, the anterior growth of the maxilla in the sagittal direction was prevented, the palatal and mandibular planes were rotated downward and backward, eruption and mesialization of the mandibular molar teeth were observed, and the mandibular anterior teeth showed uprighting rather than achieving protrusion. The authors concluded that the combined use of the two appliances completed and positively improved their effects.[11,12] The activator headgear combination used for treating growing individuals with mandibular retrognathia is an effective treatment method in correcting the sagittal imbalance by preventing antero-inferior maxillary growth while stimulating anterior mandibular development.[13-16]

To our knowledge, there has been only one study that combined TB and cervical headgear. However, that study is highly limited concerning the parameters evaluated and it also lacks a control group for distinguishing the effects of growth and development.[15] This study compared the effects of traditional TB and cervical headgear TB (CHG-TB) on skeletal, dentoalveolar, and soft tissues in individuals with mandibular retrognathia. Our null hypothesis was that there was no significant difference between these two appliances.

METHODS

Subjects

The retrospective controlled study examined lateral cephalometric radiographs taken before and after treatment/observation from 46 individuals during the growth and developmental period who were treated at Adıyaman University Faculty of Dentistry Department of Orthodontics due to increased overjet and skeletal Class II Division 1 malocclusion. Approval was obtained from the Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval date: February 16, 2021, approval no: 2021/02-32).

Sample size was calculated using GPOWER (Ver. 3.1 Franz Foul, Universitat Kiel, Germany) and the effect size was calculated with an alpha value of 0.05 and a power of 80% according to the study by Mills and McCulloch.[17] In the same study, the change in the distance between point B and vertical reference plane was 3.8±2.0 mm in the TB group and 1.7±1.7 mm in the control group. Accordingly, the effect size was found to be 1.13 and thus a minimum of 11 subjects were needed for each group. To increase the power of the study, 46 individuals from three groups were included: 15 subjects in the TB group, 16 subjects in the CHG-TB group, and 15 subjects in the control group.

The inclusion criteria were as follows: having a minimum of 4 mm overjet, mandibular retrognathia (SNB <78°), skeletal Class II malocclusion (ANB >4°), dental Class II Division 1 malocclusion (bilateral half or full-step Class II molar relationship), an SN/GoGn angle of less than 36°, normal or increased overbite, being in the onset or peak of pubertal growth spurt and having radiographic images obtained by the same operator using the same device with the patient's head and soft tissue-positioned parallel to the Frankfort horizontal plane, the teeth in centric occlusion, and the lips in a tension-free position. The exclusion criteria were as follows: syndromes, cleft lip and palate or craniofacial anomalies, prior orthodontic treatment, and missing or extra teeth. The growth and development of individuals were evaluated using wrist X-rays following the Björk method,[18] and only individuals between the S and DP3 union periods were included in the study.

Trial Design

Twin-block Appliance

The TB appliance (Figure 1A) used in the study was prepared in accordance to Clark's[3] guidelines. The maximum anterior mandibular activation was 6-7 mm and the maximum vertical mandibular activation was 4-5 mm. The appliance consisted of vestibular arches, eyelet clasps between the premolars, and Adams clasps in the molars in both the maxillary and mandibular parts. A screw was placed at the level of premolar teeth and in the midline of the upper plate to achieve a transversal expansion. The slope between the two parts of the appliance was 70°. All subjects were instructed to wear the TB appliance all day except during meal times. During monthly follow-up appointments, sagittal and transversal relationships were evaluated for each subject. The expansion screw was activated with one turn every 4 days until the transversal stenosis was resolved. The appliances were used full time for an average period of 7 months and the active phase was terminated when the canine and molars had a Class III relationship and the mandible could not be pushed back. In the supportive phase, the appliance was used only at night, and this phase lasted for an average of 4 months.

Cervical Headgear Twin-Block Appliance

During the construction stages of the TB appliance, tubes were placed on both sides of the appliance at the level of the second premolar of the maxillary plate (Figure 1B). The tubes were designed to remain embedded in the acrylic, allowing the inner arms of the cervical headgear could pass through them. Patients were provided with information on how to use both the TB appliance and the cervical headgear appliance (Figure 1C). The extraoral arms of the cervical headgear were raised at the level of the second premolars (15-30°), and care was taken to pass the maxillary dentition through or near the center of resistance. The strength of the cervical headgear was adjusted to 400-450 g, and the patients were asked to wear it with TB all day except during meal times. The force was measured at monthly controls and if it decreased, it was readjusted to 400-450 g. As with patients using TB in the active phase, the molar relationship was terminated when the molar relationship became Class III and the mandible could no longer be pushed back. The active phase lasted an average of 7 months. As with patients using TB in the supportive phase, the CHG-TB appliance was used only at night. The supportive phase lasted for an average period of 4 months.

To compare the treatment and growth effects, a control group was formed using radiographs selected from the archives. These radiographs were obtained from individuals who had registered for treatment but did not start the treatment for various reasons. Second radiographs of these individuals were obtained after a minimum of six months when they returned for a second treatment.

Analysis of Lateral Cephalometric Radiographs

Measurements of digital lateral cephalometric radiographs taken before and after treatment/observation were performed using Vistadent OC software. A total of 23 cephalometric measurements (Supplementary Table 1), including 7 angular and 16 linear measurements (Figure 2) were performed by an expert orthodontist (BG), who was blinded to the treatment group. Pre- and post-treatment radiographs were superimposed using the cephalometric superimposition method described by Björk and Skieller.[19] To detect errors in individual markings and measurements, all measurements were repeated for 15 randomly selected lateral cephalometric radiographs 21 days after the first measurements.

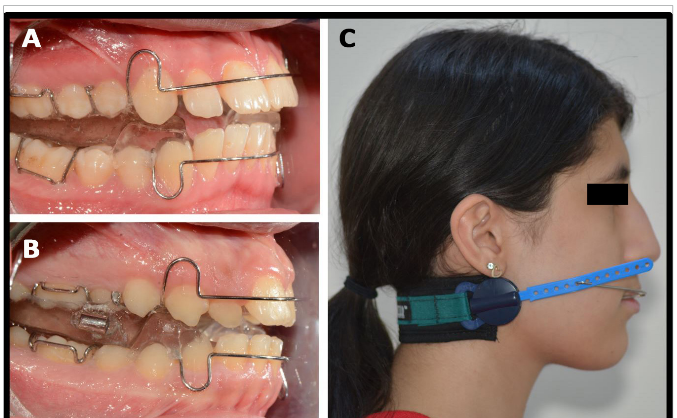

Figure 1. A. A conventional twin-block appliance, B. The twin-block part of the cervical headgear twin-block appliance, C. The cervical headgear part of the cervical headgear twin-block appliance

Statistical Analysis

Data were analyzed using SPSS software for Windows (version 22.0, IBM Corp, Armonk, NY, USA). The normal distribution of continuous variables was assessed using the Shapiro-Wilk test. One-Way ANOVA followed by post-hoc Bonferroni test was used to compare three or more groups. For in-group comparisons, dependent groups were compared using the Paired Samples t-test. The chi-square test was used for comparisons between groups with non-parametric data. Interrater reliability was assessed with an intraclass correlation coefficient (ICC). A p value of <0.05 was considered significant.

RESULTS

The results indicated that the correlation between repeated measurements was remarkably high and the coefficient was close to 1 (0.961-1). Table 1 presents a comparison of the demographic characteristics and treatment durations of the groups. No significant difference was found among the groups concerning baseline demographic characteristics (p>0.05). Similarly, there was no significant difference between the treatment groups concerning treatment/observation time (p>0.05), whereas a significant difference was found between the treatment groups and the control group (p<0.001).

Table 2 presents a comparison of the baseline cephalometric measurements of the groups. No significant difference was found among the groups concerning baseline cephalometric measurements (p>0.05).

Results of Lateral Cephalometric Radiographs

Table 3 presents a comparison of pre- and post-treatment/observation parameters. Regarding the maxillary skeletal measurements of the CHG-TB group, there was a significant decrease in the SNA angle by a mean of 1.21°±1.37° and a significant increase in the SN/PP value by a mean of 1.31°±1.78° (p<0.01). In the other groups, no significant change was found in these measurements. There was a significant increase in the A-HR value in all three groups (p<0.05), while a significant change was observed in the A-VR value only in the control group (p<0.05).

Table 1. Baseline demographic characteristics of the samples

		1. TB	2. CHG-TB	3. C	p	1 vs. 2	2 vs. 3	1 vs. 3
Age (years)		**12.34±1.23**	**12.5±1.30**	**11.82±1.16**	**0.300[a]**	**NS**	**NS**	**NS**
Gender	**Female (n)**	9	9	9	0.970[b]	NS	NS	NS
	Male (n)	6	7	6				
Maturation stage	**S**	7	8	8	0.752[b]	NS	NS	NS
	MP3cap	5	6	7				
	PP3u	1	1	0				
	DP3u	2	1	0				
Duration/Observation (months)		11.07±1.10	10.88±1.31	7.43±2.01	0.000*[a]	NS	0.000*	0.000*

TB, Conventional twin-block group; CHG-TB, cervical headgear twin-block group; C, Control group; [a], ANOVA test; [b], Chi-square test; NS, Not significant, *: p<0.05

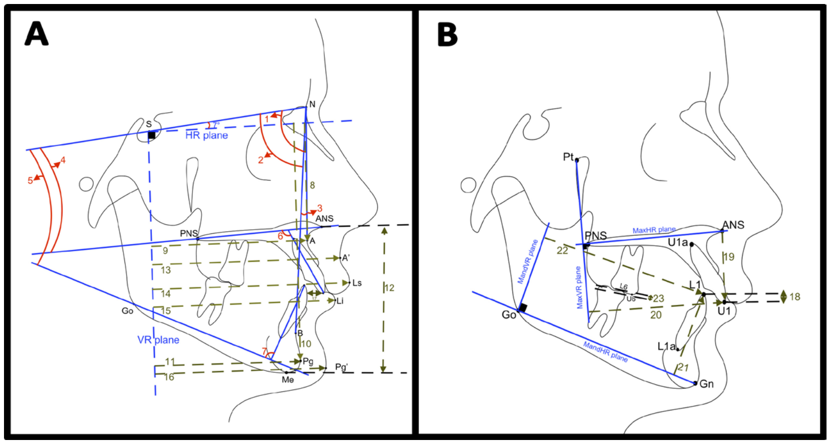

Figure 2. A. Lateral cephalometric measurements used in the study: 1. SNA (°): Angle between the S, N, and A points, 2. SNB(°): Angle between the S, N and B planes, 3. ANB(°): Angle between the N, A, and B points, 4. SN/PP(°): Angle between the plane formed by the S and N points and the plane formed by the ANS and PNS points, 5: SN/GoGn(°): Angle between the plane formed by the S and N points and the plane formed by the Go and Gn points, 6. U1/PP(°): Angle between the plane formed by the U1 and U1a points and the planes formed by the ANS and PNS points, 7. IMPA (°): Angle between the plane formed by the L1 and L1a points and the plane formed by the ANS and PNS points, 8. A-HR (mm): Distance between the A point and the HR plane, 9. A-VR (mm): Distance between the A point and the VR plane, 10. Pg-HR (mm): Distance between the Pg point and the HR plane, 11. Distance between the Pg point and VR plane, 12. ANS-Me (mm): Distance between the ANS and Me points, 13. Distance between point the A' point and the VR plane, 14. Distance between the Ls point and the VR plane, 15. Distance between the Li point and the VR plane, 16. Distance between the Pg' point and the VR plane, 17. Overjet (mm): Perpendicular distance between the U1 point and the lower incisors. B. Lateral cephalometric measurements used in the study (continued): 18. Perpendicular distance between the U1 and L1 points, 19. Perpendicular distance between the U1 point and the MaxHR plane, 20. Perpendicular distance between the U1 point and the MaxVR plane, 21. Perpendicular distance between the L1 point to the MandHR plane, 22. Perpendicular distance between the L1 point and the MandVR plane, 23. Perpendicular distance between the U6 and L6 points

Table 2. Pretreatment values of parameters for each group

Parameters		TB	CHG-TB	C			
		Mean±SD	Mean±SD	Mean±SD	F	Overall P[a] value	Significance
Maxillary skeletal measurements	SNA°	79.33±3.75	82.23±3.78	80.86±3.62	2.35	0.107	NS
	A-HR (mm)	51.57±4.72	52.31±4.55	49.90±3.20	1.32	0.278	NS
	A-VR (mm)	65.60±5.25	68.78±5.51	65.74±5.06	1.82	0.175	NS
	SN/PP°	9.33±4.32	6.56±3.35	8.20±2.70	2.44	0.099	NS
Mandibular skeletal measurements	SNB°	72.90±3.05	75.75±3.30	74.51±2.68	3.45	0.051	NS
	Pg-HR (mm)	97.70±7.03	100.94±8.54	98.57±4.49	0.911	0.410	NS
	Pg-VR (mm)	54.40±6.71	58.53±6.82	56.70±7.91	1.29	0.285	NS
	SN/GoGn°	31.73±4.14	30.80±3.64	30.75±3.82	0.31	0.735	NS
Maxillo-mandibular measurements	ANB°	6.43±2.08	6.49±1.89	6.35±1.90	0.02	0.982	NS
	ANS-Me (mm)	57.47±5.26	59.25±6.06	58.27±4.22	0.45	0.642	NS
Maxillary dental measurements	U1/PP°	116.46±11.59	118.23±5.86	119.48±5.03	0.54	0.586	NS
	U1-MaxHR (mm)	28.14±5.52	29.54±5.23	28.54±1.92	0.41	0.664	NS
	U1-MaxVR (mm)	51.73±3.52	52.57±3.82	51.23±3.62	0.50	0.608	NS
Mandibular dental measurements	IMPA°	96.80±7.88	96.75±6.54	98.73±6.85	0.38	0.683	NS
	L1-MandVR (mm)	64.13±5.88	65.81±4.78	64.73±4.79	0.422	0.658	NS
	L1-MandHR (mm)	38.13±1.82	38.91±3.53	38.13±2.29	0.436	0.649	NS
Interdental measurements	Overjet (mm)	9.69±2.50	10.06±2.28	9.33±1.85	0.41	0.663	NS
	Overbite (mm)	3.84±2.58	4.48±1.68	3.40±1.65	1.14	0.331	NS
	Posterior overbite (mm)	1.46±0.52	1.44±0.51	1.40±0.51	0.064	0.938	NS
Soft-tissue measurements	A'-VR (mm)	80.53±5.42	80.50±4.60	80.80±6.82	0.013	0.987	NS
	Ls-VR (mm)	82.10±5.90	82.28±4.98	82.06±7.28	0.006	0.984	NS
	Li-VR (mm)	75.23±6.03	75.03±6.10	75.67±6.94	0.040	0.961	NS
	Pg'-VR (mm)	64.37±8.45	64.13±7.70	64.60±7.61	0.014	0.986	NS

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; [a], ANOVA test; mm, Millimeter; SD, Standard deviation; NS, Not significant, Significance: $p<0.05$

Table 3. Comparison of pre- and post-treatment/observation parameters

	TB			CHG-TB			C		
	Pretreatment	Post-treatment	P[q]	Pretreatment	Post-treatment	P[q]	Pre-observation	Post-observation	P[q]
	Mean±SD			Mean±SD			Mean±SD		
SNA°	79.33±3.75	79.41±3.85	0.838	82.23±3.78	81.02±4.07	0.003*	80.86±3.62	81.27±3.40	0.193
A-HR (mm)	51.57±4.72	52.90±5.22	0.024*	52.31±4.55	54.47±4.88	0.002*	49.90±3.20	51.02±3.87	0.000*
A-VR (mm)	65.60±5.25	65.97±5.25	0.524	68.78±5.51	68.72±5.87	0.940	65.74±5.06	66.98±5.22	0.001*
SN/PP°	9.33±4.32	8.87±4.60	0.187	6.56±3.35	7.88±4.22	0.010*	8.20±2.70	7.67±2.92	0.120
SNB°	72.90±3.05	74.97±3.82	0.000*	75.75±3.30	76.74±3.55	0.023*	74.51±2.68	74.97±2.48	0.127
Pg-HR (mm)	97.70±7.03	102.77±7.97	0.000*	100.94±8.54	107.28±7.68	0.000*	98.57±4.49	99.97±3.95	0.002*
Pg-VR (mm)	54.40±6.71	58.10±7.59	0.000*	58.53±6.82	61.50±7.78	0.003*	56.70±7.91	58.13±7.56	0.014*
SN/GoGn°	31.73±4.14	32.00±4.51	0.395	30.80±3.64	32.59±3.73	0.001*	30.75±3.82	30.95±3.66	0.259
ANB°	6.43±2.08	4.45±2.36	0.000*	6.49±1.89	4.27±1.67	0.000*	6.35±1.90	6.30±1.87	0.650
ANS-Me (mm)	57.47±5.26	60.47±5.50	0.000*	59.25±6.06	63.69±6.10	0.000*	58.27±4.22	59.41±3.23	0.009*
U1/PP°	116.46±11.59	111.31±8.01	0.004*	118.23±5.86	108.71±7.34	0.000*	119.48±5.03	119.23±6.48	0.834
U1-MaxHR (mm)	28.14±5.52	29.87±6.85	0.040*	29.54±5.23	29.57±4.48	0.969	28.54±1.92	28.34±2.92	0.651
U1-MaxVR (mm)	51.73±3.52	50.33±3.64	0.006*	52.57±3.82	49.66±4.93	0.000*	51.23±3.62	51.49±4.58	0.665
IMPA°	96.80±7.88	100.60±5.89	0.008*	96.75±6.54	98.13±5.58	0.156	98.73±6.85	99.07±7.06	0.519
L1-MandVR (mm)	64.13±5.88	66.87±6.35	0.000*	65.81±4.78	67.16±4.58	0.000*	64.73±4.79	64.73±5.21	1.000
L1-MandHR (mm)	38.13±1.82	38.03±2.47	0.819	38.91±3.53	39.38±3.70	0.038*	38.13±2.29	38.53±2.25	0.022*
Overjet (mm)	9.69±2.50	3.65±1.38	0.000*	10.06±2.28	3.51±1.58	0.000*	9.33±1.85	9.15±2.54	0.656
Overbite (mm)	3.84±2.58	2.06±1.48	0.005*	4.48±1.68	2.78±1.68	0.001*	3.40±1.65	3.57±1.42	0.586
Posterior overbite (mm)	1.46±0.52	-1.73±1.31	0.000*	1.44±0.51	-1.69±1.94	0.000*	1.40±0.51	1.47±0.40	0.433
A′-VR (mm)	80.53±5.42	81.06±5.24	0.305	80.50±4.60	79.09±5.38	0.066	80.80±6.82	83.13±6.75	0.000*
Ls-VR (mm)	82.10±5.90	82.87±6.28	0.180	82.28±4.98	80.78±5.68	0.111	82.06±7.28	84.00±7.32	0.001*
Li-VR (mm)	75.23±6.03	78.97±7.28	0.000*	75.03±6.10	78.38±6.58	0.000*	75.67±6.94	77.93±6.94	0.001*
Pg′-VR (mm)	64.37±8.45	69.20±9.82	0.000*	64.13±7.70	67.72±8.62	0.000*	64.60±7.61	68.20±7.63	0.000*

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; SD, Standard deviation; [q], Paired Samples t-test; mm, Millimeter, *: p<0.05

Table 4 presents a comparison of the parameters among the three groups. No significant difference was found among the groups concerning A-HR and A-VR values ($p>0.05$), while the changes in SNA and SN/PP values were statistically significant in the CHG-TB group compared to other groups ($p>0.05$). However, there was no significant difference between the TB and control groups ($p>0.05$).

In mandibular skeletal measurements, the SNB angle increased significantly by a mean of 2.07°±1.50° in the TB group ($p<0.001$) and by a mean of 0.99°±1.57° in the CHG-TB group ($p<0.05$), whereas no significant change was observed in the control group. The Pg-HR and Pg-VR values increased significantly in all three groups ($p<0.05$), while the SN/GoGn value changed significantly only in the CHG-TB group. Although there was no significant difference among the three groups concerning the change in the Pg-VR value ($p>0.05$), the Pg-HR value showed a significant difference between the treatment groups and the control group ($p<0.001$). However, no significant difference was established between the treatment groups ($p>0.05$). No significant difference was observed between the TB and control groups concerning the changes in the SNB and SN/GoGn values ($p>0.05$), while significant differences were found between the CHG-TB and TB groups and between the CHG-TB and control groups ($p<0.01$).

The ANB angle decreased significantly by a mean of 1.98° in the TB group and a mean of 2.22° in the CHG-TB group ($p<0.001$), while no significant change was found in the control group ($p>0.05$). The ANS-Me value showed a significant increase in all three groups ($p<0.01$). Although no significant difference was found between the treatment groups concerning the change in the ANB angle ($p>0.05$), a significant difference was observed

Table 4. Comparison of the parameters among the three groups

		1. TB Mean±SD	2. CHG-TB Mean±SD	3. C Mean±SD	P[a]	1-2	1-3	2-3
Maxillary skeletal measurements	**SNA°**	0.07±1.36	-1.21±1.37	0.41±1.17	0.003*	0.027*	NS	0.004 *
	A-HR (mm)	1.33±2.03	2.16±2.32	1.12±0.88	0.273	NS	NS	NS
	A-VR (mm)	0.37±2.18	-0.06±3.26	1.24±1.15	0.309	NS	NS	NS
	SN/PP°	-0.47±1.30	1.31±1.78	-0.53±1.25	0.001*	0.005 *	NS	0.003*
Mandibular skeletal measurements	**SNB°**	2.07±1.50	0.99±1.57	0.46±1.10	0.010*	NS	0.009*	NS
	Pg-HR (mm)	5.07±1.57	6.34±3.36	1.40±1.42	0.000*	NS	0.000*	0.000*
	Pg-VR (mm)	3.70±2.66	2.97±3.40	1.43±1.99	0.083	NS	NS	NS
	SN/GoGn°	0.27±1.18	1.79±1.67	0.20±0.66	0.001*	0.006*	NS	0.001*
Maxillo-mandibular measurements	**ANB°**	-1.98±0.90	-2.22±1.09	-0.05±0.45	0.000*	NS	0.000*	0.000*
	ANS-Me (mm)	3.00±1.65	4.44±1.41	1.14±1.47	0.000*	0.034*	0.005*	0.000*
Maxillary dental measurements	**U1/PP°**	-5.15±5.89	-9.53±5.35	-0.25±4.47	0.000*	NS	0.044*	0.000*
	U1-MaxHR (mm)	1.73±3.04	0.03±3.21	-0.20±2.01	0.111	NS	NS	NS
	U1-MaxVR (mm)	-1.40±1.64	-2.91±2.55	0.26±1.83	0.001*	NS	NS	0.000*
Mandibular dental measurements	**IMPA°**	3.80±4.78	1.38±3.69	0.33±1.95	0.038*	NS	0.039*	NS
	L1-MandVR (mm)	2.73±1.43	1.34±0.93	0.00±0.94	0.000*	0.004*	0.000*	0.005*
	L1-MandHR (mm)	-0.10±1.66	0.47±0.83	0.40±0.60	0.320	NS	NS	NS
Interdental measurements	**Overjet (mm)**	-6.04±1.98	-6.55±2.41	-0.18±1.53	0.000*	NS	0.000*	0.000*
	Overbite (mm)	-1.78±2.08	-1.71±1.75	0.17±1.16	0.004*	NS	0.010*	0.012*
	Posterior overbite (mm)	-3.20±1.35	-3.13±2.05	0.07±0.32	0.000*	NS	0.000*	0.000*
Soft-tissue measurements	**A'-VR (mm)**	0.53±1.94	-1.41±2.84	2.33±1.54	0.000*	NS	NS	0.000*
	Ls-VR (mm)	0.76±2.10	-1.50±3.54	1.93±1.79	0.002*	NS	NS	0.002*
	Li-VR (mm)	3.73±2.74	3.34±2.45	2.27±2.08	0.244	NS	NS	NS
	Pg'-VR (mm)	4.83±3.46	3.59±2.53	3.60±2.90	0.426	NS	NS	NS

TB, Conventional twin-block group; CHG-TB, Cervical headgear twin-block group; C, Control group; SD, Standard deviation; [a], ANOVA test; mm, Millimeter, *: p<0.05

between the treatment groups and the control group (p<0.001). The change in the ANS-Me value showed a significant difference among all three groups (p<0.05).

In terms of maxillary dental measurements, the U1/PP and U1-MaxVR values showed a significant decrease in both treatment groups (p<0.01). The U1-MaxHR value showed a significant change only in the TB group. In the control group, no significant change was observed in the U1/PP and U1-MaxVR values. There was no significant difference found between the treatment groups concerning the changes in maxillary measurements (p>0.05). While a significant difference was observed between the treatment groups and the control group regarding the change in the U1/PP value (p<0.05), the U1-MaxVR value showed a significant difference only between the CHG-TB and control groups (p<0.001).

The IMPA value increased significantly only in the TB group (p<0.01), whereas the L1-MandVR value increased significantly in both treatment groups (p<0.001). The L1-MandHR value showed a significant change in the CHG-TB and control groups (p<0.05). Although no significant difference was found among the three groups concerning the change in the L1-MandHR value (p>0.05), a significant difference was observed between the TB and control groups concerning the change in the IMPA value. The change in the L1-Mand VR value showed a significant difference among all three groups (p<0.01).

In interdental measurements, both treatment groups showed a significant decrease in overjet, overbite, and posterior overbite (p<0.01), while no significant change was observed in the control group (p>0.05). No significant difference was found between the treatment groups concerning the changes in those values (p>0.05), but a significant difference was found between the treatment groups and the control group (p<0.05).

In soft tissue measurements, both treatment groups showed a significant increase in Li-VR and Pg'-VR values (p<0.001), while no significant change was observed in the Ls-VR and A'-VR values (p>0.05). In the control group, a significant increase was observed in all of these measurements ().

DISCUSSION

This study compared the effects of full-time use of an appliance combining CHG-TB with a conventional TB appliance and an untreated control group and found significant differences among the groups. Accordingly, the null hypothesis was rejected. Our findings indicated no significant difference between the TB and control groups during the treatment/observation period concerning the change in maxillary skeletal measurements. Some researchers[20-22] have shown that TB significantly limited the maxillary growth, while other researchers, in line with our findings, have reported that it had no significant effect on maxillary growth.[23,24] Clark[25] suggested that TB should be used along with headgear when it is necessary to limit the sagittal growth of the maxilla and stimulate mandibular development. In our study, the SNA angle decreased significantly in the CHG-TB group compared to the other two groups (p<0.01). In line with our findings, studies in the literature[12,15] on the functional appliance-cervical headgear have also reported a significant limiting effect on the maxilla. Our results showed that the CHG-TB appliance could be applied when a limiting effect on the maxilla is desired. Moreover, the CHG-TB appliance was found to significantly rotate the maxilla clockwise. Similarly, Pfeiffer and Grobéty.[12] reported that the SHG-activator combination increased the palatal plane by 2°. This finding could be explained by the fact that the force vector passes well below the center of resistance of the maxilla through the combined use of cervical headgear and the functional appliance.

In our study, a significant increase was observed in the TB group concerning the sagittal movement of the mandible, and a significant increase was observed in the same group and compared to the control group regarding the SNB angle. The effect of functional appliances on mandibular growth remains controversial, with some studies reporting significant mandibular movement in the sagittal direction compared to the control group,[23,24] while others[17] have reported no significant effect. This controversy could be due to the differences in the designs of the appliances, daily usage time, and the amount of mandibular activation. In our study, although the anterior movement of the mandible was statistically significant in the CHG-TB group, no significant difference was found compared with the control group. This finding suggests that the posterior force exerted by the CHG-TB appliance on the maxilla may be transmitted to the mandible through TB and partially limit the anterior movement of the mandible. Additionally, a significant posterior rotation of the mandible was observed in the CHG-TB group compared to the TB and control groups, likely due to the force exerted distally and inferiorly by the cervical headgear attached to the TB appliance, causing clockwise rotation of the maxilla and posterior rotation of the mandible. Because of these effects, the increase in lower facial height (ANS-Me) was significantly higher in the CHG-TB group than in the other groups. Therefore, the CHG-TB appliance may not be suitable for individuals with a tendency towards vertical growth.

In our study, significant improvements were observed in the sagittal relationship between the jaws (ANB) in both treatment groups compared with the control group. The decrease in the ANB angle was due to the increase in the SNB angle in the TB group and due to the increase in the SNB angle and the significant decrease in the SNA angle in the CHG-TB group. These findings are consistent with those of the TB[22,26,27] and functional appliance-headgear[12,13] studies in the literature.

Our findings also revealed a significant retroclination of the maxillary incisors in both treatment groups compared with the control group. This finding is consistent with the TB studies in the literature[20,26,28,29] and can be explained by the fact that the anterior positioning of the mandible by conventional TB exerts a distal force on maxillary teeth, based on the action and reaction principle. Moreover, it was also observed that this decrease was higher and the distal movement of the upper incisors was statistically significant in the CHG-TB group compared with the control group. In addition to the force exerted by the TB appliance on the maxillary teeth, the distalizing effect of the cervical headgear may have contributed to this result. This finding is consistent with the those of activator-headgear studies in the literature.[13,16,30] Based on these findings, we suggest that the CHG-TB appliance can be recommended in cases with proclined maxillary incisors, whereas this appliance may be avoided or only applied with torque springs if the maxillary incisor angles are within normal limits.

In our study, although the mandibular incisors protruded and proclined significantly in the TB group compared with the control group, no significant change was observed in the CHG-TB group compared with the control group. Lower incisor proclination, which is a frequently reported side effect of TB, was statistically insignificant in the CHG-TB group.[20,31,32] In the CHG-TB appliance, the protrusion force on the mandibular anterior teeth decreases due to the distalizing force on the upper part of the TB appliance. This notion could explain the lower proclination observed in the mandibular anterior teeth. Additionally, retroclinations of the maxillary incisors in the CHG-TB group may have prevented the protrusion of the lower incisors.

In this study, a significant decrease was found in overjet and overbite measurements in both groups compared with the control group, and there was no significant difference between the two treatment groups. This finding is consistent with previous studies on TB[7,17,21,23,24,26,28,29] and activator-headgear appliances.[13,14] Additionally, lateral open bite was observed in both treatment groups. DeVincenzo[33] reported a posterior open bite after the administration of the TB appliance, which could be attributed to the posterior acrylic blocks that prevent tooth eruption after anterior relocation of the mandible by the TB appliance. Although there was no significant difference between the two treatment groups in our study regarding soft tissue measurements, maxillary soft tissues showed significant retrusion in the CHG-TB group compared with the control group. Therefore, it is predictable that the maxillary soft tissues would move posteriorly after the retrusion of the maxillary base and incisors in the CHG-TB group.

The first limitation of this retrospective study was that it only evaluated the immediate effects of two different appliances.

Therefore, further studies evaluating long-term changes are needed to investigate treatment stability in patients. The second limitation was that the follow-up period of the control group, which was used to compare treatment effects with growth effects, was shorter than that of the treatment groups. This may be clinically significant, and further prospective studies with treatment and follow-up periods across all groups are necessary. Additionally, different appliance models should be studied with different age groups and larger sample sizes.

CONCLUSION

The conclusions drawn from our findings can be summarized as follows:

- The CHG-TB combination was more effective in limiting maxillary development in the sagittal direction, but had greater side effects of upper incisor retroclination.
- The conventional TB appliance was more effective in mandibular movement in the sagittal direction, but had greater side effects of lower incisor proclination.
- There was no significant difference between the two appliances in terms of their effects on maxillary and mandibular soft tissues.

Ethics

Ethics Committee Approval: An approval was obtained from Adıyaman University Non-Interventional Clinical Research Ethics Committee (approval date: February 16, 2021, approval no: 2021/02-32).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.A.Y.; Design - M.A.Y.; Supervision - M.A.Y.; Materials - B.G.; Data Collection and/or Processing - B.G.; Literature Review - M.A.Y.; Writing - M.A.Y.; Critical Review - M.A.Y.

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Supplementary Table 1. Cephalometric landmarks and planes

Variables	Definition
Landmarks	
S	Geometrical midpoint of sella turcica
N	The deepest and most anterior point where the frontonasal suture intersects the middle oxal plane
A	The deepest point of the bony concavity between the anterior nasal spine and the upper incisors
B	The deepest point of the bone concavity that lies between the lower incisors and the tip of the jaw
ANS	The most extreme point of the maxillary prominence at the base of the anterior nasal opening
PNS	Most posterior and end point of the maxillary hard palate in the sagittal plane on lateral cephalometric radiographs
U1	Apex of the incisal edge of the maxillary central incisor
U1a	Apex of the maxillary central incisor
L1	Apex of the incisal edge of the mandibular central incisor
L1a	Apex of the mandibular central incisor
U6	Apex of the mesiobuccal tubercle of the maxillary first molar
L6	Apex of the mesiobuccal tubercle of the mandibular first molar
Gn	Midpoint of the structure between the most anterior and lowest points in the outer contour of the mandibular symphysis
Me	Lowest point in the vertical plane on the outer borders of the mandibular symphysis
Go	The point where the bisector of the angle formed by drawing tangents to the posterior edge of the mandibular ramus and the lower edge of its corpus intersects with the mandibular angle
Ls	The most anterior point of the upper lip in the sagittal plane
Li	The most anterior point of the lower lip in the sagittal plane
A'	The deepest point between the subnasale point and the most forward point of the upper lip in the sagittal plane
Pg'	The most anterior point of the chin soft tissue in the sagittal plane
Planes	
HR	Horizontal reference plane: the plane created by drawing 7° below SN through the S point
VR	Vertical reference plane: the plane created by drawing 90° perpendicular to the HR plane through the S point
MaxHR	Maxillary horizontal reference plane: the plane connecting the ANS and PNS points
MaxVR	Maxillary vertical reference plane: the plane perpendicular to the MaxHR plane from the Pt point
MandHR	Mandibular horizontal reference plane: the plane connecting the Go and Gn points
MandVR	Mandibular vertical reference plane: the plane perpendicular to the MandHR plane from the Go point