ОРТОДОНТІЯ

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COMPARATIVE CEPHALOMETRIC ANALYSIS OF TWIN BLOCK AND MODIFIED FUNCTIONAL APPLIANCES ON UPPER AIRWAY DIMENSIONS IN CLASS II MALOCCLUSION PATIENTS WITH NARROWED UPPER AIRWAY

Introduction: *Class II malocclusion is a common issue in orthodontics, particularly in patients with a retrognathic mandible. Functional appliances, such as the twin-block appliance, are often used to encourage mandibular growth during orthodontic treatment. However, the effect of this appliance on upper airway dimensions remains unclear.*

Objective: *The objective of this study was to compare the effectiveness of the twin-block and modified functional appliances in terms of cephalometric parameter changes during orthodontic treatment for patients with skeletal Class II malocclusion, retrognathic mandible, and narrowed upper airway. The study aimed to monitor changes in these parameters over time to evaluate the efficacy of the appliances.*

Methods: *This study analyzed cephalometric radiographs of 104 children, aged 7 to 13, with skeletal Class II malocclusion, retrognathic mandible, and narrowed upper airway during the mixed dentition stage at the pubertal stages of CS3 and CS4. These children received treatment at the Department of Orthodontics of the Shupyk National Healthcare University of Ukraine.*

Results: *The modified functional appliance (MFA) proposed in this study for children with Class II malocclusion has the ability to eliminate morphological, physiological and aesthetic disorders, restore the function of the masticatory system, normalize the position of the hyoid bone, adjust the inclination of the soft palate, adapt the cervical spine, and correct the tilt of the head. Additionally, it can widen the upper airway (oropharynx and hypopharynx) and provide aesthetic treatment results in a shorter amount of time when compared to using a twin-block appliance.*

Conclusions: *The results indicate that functional orthopedic treatment can be an effective treatment option for patients with upper airway and malocclusion issues.*

Key words: *Class II malocclusion, Twin-block, Modified functional appliance, Cephalometric radiographs, Upper airway.*

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ПОРІВНЯЛЬНИЙ ЦЕФАЛОМЕТРИЧНИЙ АНАЛІЗ РОЗМІРІВ ВЕРХНІХ ДИХАЛЬНИХ ШЛЯХІВ З ВИКОРИСТАННЯМ ЗДВОЄНИХ БЛОКІВ І МОДИФІКОВАНИХ ФУНКЦІОНАЛЬНИХ ПРИСТОСУВАНЬ У ПАЦІЄНТІВ З АНОМАЛІЯМИ ПРИКУСУ II КЛАСУ ЗІ ЗВУЖЕННЯМ ВЕРХНІХ ДИХАЛЬНИХ ШЛЯХІВ

Вступ. *Дистальний прикус є однією з найчастіших проблем у практиці ортодонтії. У випадках дистального прикусу та ретрогнатичного положення нижньої щелепи, функціональні пристрої часто використовуються для стимуляції росту нижньої щелепи під час ортодонтичного лікування. Один з найпопулярніших функціональних пристроїв для лікування дистального прикусу – це Твін-блок. Однак, ефект його застосування на розміри верхніх дихальних шляхів залишається невизначеним.*

Мета. *Порівняння результатів ефективності впливу запропонованого модифікованого функціонального апарату та Твін-блоку на зміни показників ТРГ у динаміці ортодонтичного лікування пацієнтів із селективними формами дистального прикусу, ретрогнатичною нижньою щелепою та звуженням верхніх дихальних шляхів.*

Методи дослідження. *Нами проведено аналіз цефалометричних рентгенограм у 104 дітей із скелетними формами дистального прикусу та звуженням верхніх дихальних шляхів у періоді змінного прикусу, на піку зростання (CS3 і CS4 – пубертальні стадії) віком від 7 до 13 років на кафедрі ортодонтії Національного університету охорони здоров'я України імені П. Л. Шупика.*

Результати. *Запропонований модифікований функціональний пристрій (МФП) дозволяє усунути морфологічні порушення, відновити функцію жувальної системи, нормалізувати положення під'язикової кістки, нахил м'якого піднебіння, адаптацію шийного хребця і корекцію нахилу голови, а також розширити верхні дихальні шляхи (ротоглотки, гортаноглотки) та забезпечити естетичні результати лікування у коротші терміни порівняно з застосуванням твінблоку.*

Висновки. *Застосування функціональної апаратури у дітей із скелетними формами дистального прикусу є обов'язковою складовою ортодонтичного втручання, оскільки усуває патологію прикусу та відновлює функціонування зубо-щелепової системи.*

Ключові слова: *дистальний прикус, твін-блок, модифікований функціональний апарат, ТРГ.*

Introduction

Class II malocclusion is a prevalent orthodontic problem, with both skeletal and dental causes. Clinical manifestations of this malocclusion are varied and can include mandibular deficiency and maxillary protrusion [1–4]. Class II malocclusion can cause a range of morphological, psychological, functional, and aesthetic alterations, including disruptions to the balance of the surrounding muscles, impacting functions such as breathing, speech, chewing, and swallowing. Additionally, the interplay between facial muscle function and the psyche is evident, particularly in cases where lip closure is not achieved. The resultant deformation of the facial skeleton and disharmony of the face can contribute to a shy and introverted appearance, which can lead to communication difficulties for children with Class II malocclusion.

Growing patients who have Class II malocclusion with a retrognathic mandible are increasingly being identified as exhibiting a physiological characteristic of a narrowed upper airway [5–7]. Changes in the volume of the pharynx can occur due to disturbances in the growth and development of the upper and lower jaws resulting from developmental deformities, orthognathic surgery, or orthodontic treatment [8, 9]. The results of our previous studies have established a significant association between mandibular retrusion, displacement of the hyoid bone and changes in upper airway volume [10, 11].

Such compensatory changes in the upper airway can have negative impacts on lower airway function, including lung function, and increase the risk of daytime breathing difficulties, snoring, and obstructive sleep apnea syndrome (OSAS) during the night [12, 13].

Removable functional appliances, including Activator, Bionator, Frankel, and Twin-block (TB), are commonly used to treat Class II malocclusion [14–16]. When diagnosed early, skeletal Class II malocclusion can be effectively treated with functional appliances that encourage forward mandibular growth and prevent posterior movement of the tongue, thereby preventing the collapse of the upper airway during sleep [16, 17]. The Twin-block (TB) appliance, developed by William J. Clark in 1982, is widely used to treat sagittal occlusal anomalies by inducing functional displacement of the mandible [16, 18–26]. However, the effectiveness of TB in normalizing respiratory function is a subject of debate among researchers, with some studies suggesting that TB can increase the dimension of the upper airway by promoting forward mandibular movement [16, 19–24], while negative observations have also been reported [25, 27]. Our research has led to the development of a modified functional appliance (Fig. 1) to treat skeletal Class II malocclusion in children with a retrognathic mandible and narrowed upper airway.

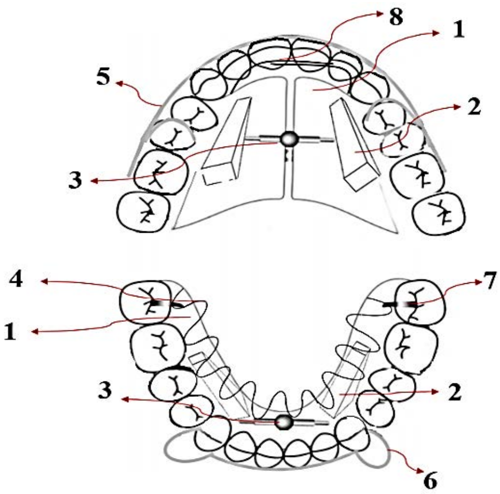

Fig. 1. Depicts the design of our modified functional appliance for treating skeletal Class II malocclusion in children with a retrognathic mandible and narrowed upper airway. The appliance consists of acrylic bases (1) with lingual-palatal tracks (inclined planes) (2) and upper and lower middle screws (3). Additionally, the appliance includes a Lower Wavy Bar (4), a Bimler upper arch (5), a lower vestibular arch (3x3, from canine to canine) (Labial bow) (6), lower occlusal stops (7) and a protraction arch (arc extenders) (8).

The design of the modified functional appliance with palato-lingual tracks (inclined planes) that incline at an angle of 45° allows for freedom of physiological movements of the teeth, which is beneficial in preventing interference with tooth eruption and reducing the risk of gum injury. Additionally, the occlusal forces generated by the inclined planes encourage forward mandibular growth during closure or swallowing, which is important for correcting skeletal Class II malocclusion. On the other hand, the twin-block appliance can cause interference with occlusion and pressure on the teeth, which can lead to changes in the inclination of the premolar teeth.

The modified functional appliance is an effective tool for correcting skeletal Class II malocclusion, as it utilizes several mechanisms to promote forward and downward rotation of the mandible. The wavy bar along the mandible encourages the tongue to rest in a physiological position during swallowing, improving airway patency and respiratory function. Lower occlusal stops help to control the rotation of the occlusal plane and promote dentoalveolar elongation of the upper teeth.

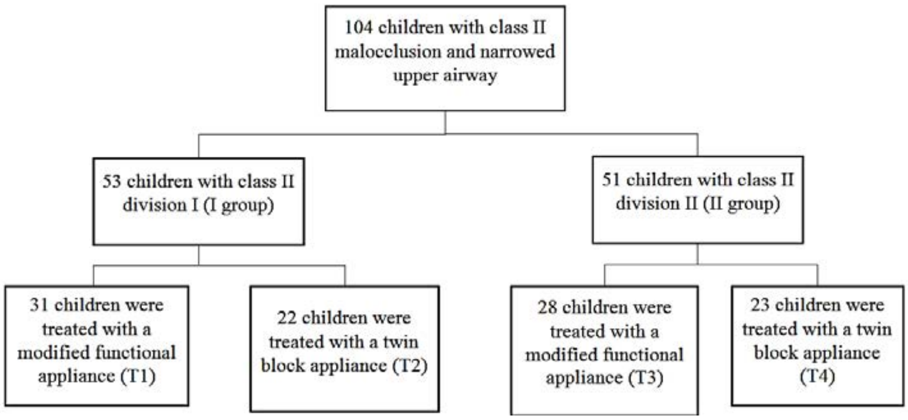

Fig. 2. Distribution of patients of research groups

Aside from correcting malocclusion, the appliance offers other benefits, such as improved masticatory function, repositioning of the hyoid bone, adaptation of the cervical vertebrae, correction of head tilt, and enhancement of aesthetic outcomes. For Class II Division II malocclusion, protraction arches may be added to align the upper central incisors.

The appliance can also promote the expansion of the upper airway, which enhances respiratory function. To achieve optimal results, it is recommended to wear the appliance continuously, except during meal times. Overall, the modified functional appliance is an effective and versatile tool for correcting skeletal malocclusion and improving various aspects of oral and respiratory function.

Materials and Methods. The present study investigated 104 growing subjects between the ages of 7 to 13, who exhibited skeletal Class II malocclusion, mandibular retrusion, and narrowed upper airway during the mixed dentition stage, especially at the pubertal stages of CS3 and CS4. The subjects received treatment at the Department of Orthodontics of the Shupyk National Healthcare University of Ukraine.

The conditions of the subjects were analyzed using cephalometric radiographs. This imaging technique provided detailed measurements of the skeletal and dental structures of the subjects, enabling accurate assessment of their malocclusion and airway narrowing.

The present study included 104 children who were divided into two groups based on their malocclusion type. Group I consisted of 53 children with Class II Division I malocclusion, while Group II comprised 51 children with Class II Division II malocclusion. Each group was further divided into two subgroups based on the type of appliance used for treatment.

Subgroup 1 of Group I included 31 children who underwent orthodontic treatment with the modified functional appliance (MFA), while Subgroup 2 included 22 children treated with the twin-block appliance. Similarly, Subgroup 1 of Group II comprised 28 children treated with the MFA, while Subgroup 2 included 23 children treated with the twin-block appliance.

A control group of 30 children with normal occlusion (Class I) and without any respiratory disorders was also included in the study. The study design allowed for the comparison of treatment outcomes between the different subgroups and the control group (see Fig. 2).

To evaluate the width of the pharynx (including the nasopharynx, oropharynx, and hypopharynx), as well as determine the growth pattern of the facial profile and the position of the jaws, the researchers utilized McNamara's cephalometric study of the respiratory tract [28]. Figure 3 illustrates the linear and angular measurements utilized in cephalometric analysis.

Lateral cephalometric images were taken both prior to and at varying time intervals following orthodontic treatment, and were analyzed using Dolphin Imaging 11.95 software and ImageJ 1.52.

To ensure the validity and reliability of the study, IBM SPSS Statistics v26 2019 software was used for analysis, and the level of significance was determined using the Chi-square test.

The average changes in parameters were compared between each group that used the MFA appliance or the twin-block in the treatment, using an independent t-test with a significance level of $P \leq 0.05$. These statistical analyses allowed for a comprehensive evaluation of the treatment outcomes and comparison of the effectiveness of the different orthodontic appliances used in the study.

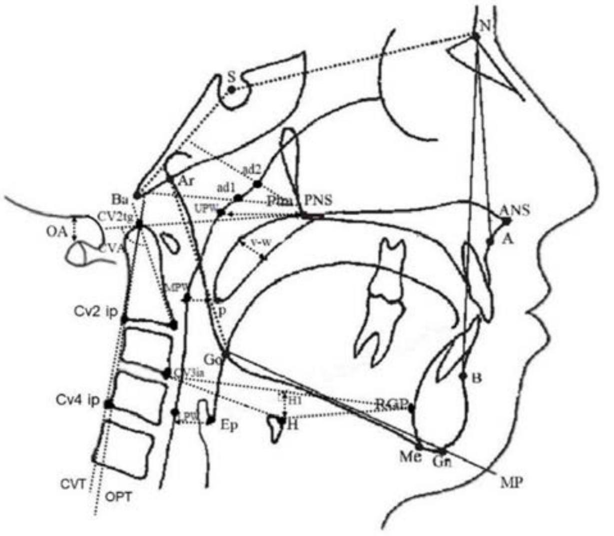

Fig. 3. Linear and angular measurements in cephalometric analysis: (anatomic parameters: N, nasion; S, sella; A; Point A, B; Point B, Pog; pogonion, Gn; gnathion, Me; menton, GO; gonion, Ba; Basion, Ptm; pterygomaxillary, RGN; Retrognathia, ANS; Anterior nasal spine, PNS; Posterior nasal spine, H Hyoidale; Anterior-superior point of the hyoid bone, Cv3ia; Anterior-inferior point on the body of the third cervical vertebra C3, Cv4ip; Inferior-posterior point on the body of the fourth cervical vertebra Cv4, Cv2ip; Inferior-posterior point on the body of the fourth cervical vertebra of the second cervical vertebra Cv2, P; uvula tip of the soft palate, Ep; epiglottis, UPW (upper pharyngeal wall); the line PNS and posterior pharyngeal wall, MPW (middle pharyngeal wall); Horizontal line from the tip of the soft palate ’P’ to posterior pharyngeal wall, LPW (lower pharyngeal wall); the line from ‘Ep’ to posterior pharyngeal wall, PPH, refers to the horizontal counterpoints of the front wall of the pharynx on the back wall of the pharynx in its narrowest section, PH; refers to the horizontal counterpoints of the back wall of the pharynx on the back wall of the pharynx in its narrowest section, PL; palatal plane, ML: mandibular plane, MGP; McGregor's Plane, OPT; Odontoid Plane, OPT tg.; Odontoid Plane tangent, CVT tg.; cervical vertebrae tangent, CVA; craniovertebral angle, V-W; Thickness of soft palate (velum), OA; Occipito-Atlas distance)

The results of this study will provide valuable information on the efficacy of different orthodontic appliances for treating skeletal Class II malocclusion and associated respiratory disorders in growing children. This knowledge can help to improve clinical decision-making and treatment outcomes for these patients.

Results. The results of the pre-treatment cephalometric analysis in the research groups' patients demonstrated significant changes in various parameters, which are presented in **Table** 1. These changes included alterations in the NA-Pog and SN-Pog angles, Upper 1 to palatal plane, Upper 1 to NA (°), Upper 1 to NA (mm), Lower 1 to NB (°), Lower 1 to NB (mm), interincisal angle, overjet, nasolabial angle, labiomental angle, upper lip-E distance, lower lip-E distance, hyoid bone angle (H-RGP-cv3ia), and H-H1 distance compared to the control parameters. The changes indicated the movement of the hyoid bone in the back-lower direction.

Moreover, an increase in PNS-P distance (mm) and V-W (mm) demonstrated an increase in the length and thickness of the soft palate. The study also found an increase in the craniovertebral angle (CVA) and OPT / CVT angle, and a decrease in the Occipito-Atlas (OA) distance due to the posterior rotation of the head and cervical vertebrae, resulting in a reduced distance between the cervical spine and mandible and a pronounced narrowing of the upper airway.

Furthermore, the study revealed that patients with Class II malocclusion with retrognathic mandibles exhibited a significantly narrowed oropharynx and hypopharynx, as indicated by the reduced P-MPW, PPH-PH, and Ep-LPW measurements compared to the control parameters. These findings suggest that retrognathic mandibles may contribute to upper airway narrowing, which can have implications for the diagnosis and treatment of sleep-disordered breathing.

Table 2 presents the modifications observed in cephalometric parameters subsequent to functional orthopedic treatment. During orthodontic treatment, there were no significant differences in measurements of the skull base and sagittal ratio of the maxilla (SNA) between the study and control groups.

The effectiveness of using either of the functional appliances in promoting the forward growth of the mandible (SNB) was found to be equal in both subgroups of the research groups.

The height of the lower third of the face (PL-ML) and the Frankfort mandibular angle (FMA) increased in both subgroups of the research groups at all follow-up periods, particularly in children treated with the Twin Block, compared to the values of the control group. This increase can be attributed to the clockwise rotation of the mandible, which leads to the opening of the angle of the mandible and an increase in the height of the lower third of the face in the case of the use of functional appliances.

However, based on these results, the use of the Twin Block may not be recommended in patients with excessive lower facial height and/or open bite.

The study found that both groups of patients who underwent treatment with different functional

Table 1

Cephalometric measurements of research group patients before orthodontic treatment.

Cephalometric parameters	Control group (C) (n=30)	53 children with class II division I (I group)		51 children with class II division II (II group)		Comparison between groups					
		MFA (T1) (n=31)	TB (T2) (n=22)	MFA (T3) (n=28)	TB (T4) (n=23)						
	Mean± SD	Mean± SD	Mean± SD	Mean± SD	Mean± SD	T1-C	T2-C	T1-T2	T3-C	T4-C	T3-T4
Measuring the base of the skull											
NS	68.51±3.68	68.33±6.49	67.74±6.04	67.13±6.19	67.01±5.19						
S-BA	46.41±5.37	45.21±2.12	46.11±2.42	44.51±2.21	44.21±2.32						
N-Ba	106.7±2.63	105.6±9.41	105.1±8.21	106.5±8.41	105.1±8.21						
S-Ptm	45.53±3.89	45.64±4.49	46.43±5.39	44.34±4.59	44.64±4.39						
BaSN	134.8±3.76	132.4±4.39	133.1±5.09	133.3±3.21	131.4±4.29						
Measurement of the ratio of sagittal and vertical jaws											
SNA	82.71±1.35	84.01±3.34	82.31±4.52	81.84±2.14	81.71±3.24						
SNB	80.25±0.14	76.5±1.21	75.1±1.31	74.8±2.19	74.1±1.91	*	*		*	*	
ANB	2.89±0.46	6.35±1.96	6.14±1.24	5.83±1.24	5.14±1.34	*	*		*	*	
PL to ML	23.87±1.41	23.79±4.23	24.19±4.11	24.12±3.79	23.79±3.31						
FMA	32.38±4.25	32.16±4.31	31.42±3.34	30.96±3.41	31.21±3.53						
NA-Pog	177.4±8.14	182.9±9.21	183.4±8.33	184.4±8.64	185.3±6.25	*	*		*	*	
SN-Pog	80.94±4.1	74.47±4.32	73.11±3.14	74.32±4.14	74.68±3.44	*	*		*	*	
Dentoalveolar changes											
Upper 1 to palatal plane	103.2±4.36	114.4±7.25	113.1±6.94	93.74±6.41	92.47±6.14	*	*		*	*	
Upper 1 to NA (°)	23.35±1.98	26.14±3.12	27.37±4.21	18.8±1.41	17.23±1.54	*	*		*	*	
Upper 1 to NA (mm)	5.33±2.03	6.11±3.14	6.74±2.14	2.76±1.31	1.44±1.19	*	*		*	*	
Lower 1 to NB (°)	25.61±2.74	21.47±2.78	21.77±2.76	21.11±2.65	21.39±2.88	*	*		*	*	
Lower 1 to NB)mm)	5.12±1.65	2.11±1.34	2.67±1.19	1.98±1.31	2.07±1.24	*	*		*	*	
Interincisal angle	132.5±7.36	139.1±7.21	140.3±8.33	124.6±6.35	123.7±7.14	*	*		*	*	
Overjet	3.81±1.65	9.32±2.31	8.79±3.41	1.32±1.43	1.19±1.11	*	*		*	*	
Nasolabial angle	105.7±8.73	99.34±7.75	98.44±5.41	109.1±6.11	108.9±7.31	*	*		*	*	
Labiomental angle	121.5±7.11	103.4±6.09	100.8±7.17	107.3±7.47	106.4±6.79	*	*		*	*	
Upper lip-E distance	-0.13±0.16	2.14±1.31	2.09±1.24	-1.89±1.04	-1.76±1.21	*	*		*	*	
Lower lip-E distance	1.15±1.12	-0.5±0.39	-0.74±0.35	-4.71±2.52	-4.94±3.41	*	*		*	*	
Measurement of the hyoid bone											
H- RGP-cv3ia	25.97±3.41	35.74±5.33	35.14±5.17	37.25±5.87	36.24±5.14	*	*		*	*	
RGP-cv3ia-H (H-H1)	5.34±2.14	14.06±3.09	15.14±5.33	14.37±5.45	14.91±4.41	*	*		*	*	
Measurement of the soft palate											
Pns-P	32.74±2.14	38.26±3.84	37.11±3.14	37.21±4.04	37.31±3.31	*	*		*	*	
V-W	9.74±2.11	13.41±3.67	12.21±3.34	13.24±3.22	13.31±3.04	*	*		*	*	
The position of the cervical vertebrae											
CVA	104.1±5.32	118±8.54	114±6.21	109±7.26	114±6.54	*	*		*	*	
OPT/CVT	1.21±1.47	4.39±1.51	4.49±1.41	3.91±1.23	3.49±1.63	*	*		*	*	
O-C1	6.44±2.34	2.14±3.44	2.04±1.23	1.73±1.02	1.94±1.23	*	*		*	*	
Measurement of the nasopharynx											
Ba-Ptm	40.14±2.32	38.56±3.26	38.46±2.14	37.82±2.14	37.46±1.19						
Ba-PNS	43.11±2.32	41.62±3.81	40.92±1.41	40.21±1.11	39.92±1.61						
PNS-ppw	25.11±2.13	23.37±1.65	24.17±2.62	23.36±1.81	22.97±1.13						
Measurement of the oropharynx											
P-MPW	13.14±1.31	8.81±2.06	8.34±2.85	8.27±2.18	8.13±2.14	*	*		*	*	
PPH-PH	9.91±1.93	5.33±1.64	5.24±1.22	4.82±1.31	4.24±1.02	*	*		*	*	
Measurement of the hypopharynx											
Ep-LPW	18.31±1.32	12.48±2.08	12.38±2.11	11.88±2.19	12.18±2.75	*	*		*	*	

C: control group, MFA: Modified functional appliance, TB: Twin-block.

** p≤0.05 – the statistical significance in the differences of the differences of parameters*

Table 2

Cephalometric measurements of research group patients after orthodontic treatment.

Cephalometric parameters	Control group (C) (n=30)	53 children with class II division I (I group)						51 children with class II division II (II group)						Comparison between groups											
		MFA (T1) (n=31)			TB (T2) (n=22)			MFA (T1) (n=31)			TB (T2) (n=22)														
	Mean ± SD	Before Mean ± SD	10-12 mo. (T1) Mean ± SD	12-16 mo. (T2) Mean ± SD	Before Mean ± SD	10-12 mo. (T3) Mean ± SD	12-16 mo. (T4) Mean ± SD	Before Mean ± SD	10-12 mo. (T5) Mean ± SD	12-16 mo. (T6) Mean ± SD	Before Mean ± SD	10-12 mo. (T7) Mean ± SD	12-16 mo. (T8) Mean ± SD	T1- C	T2- C	T3- C	T4- C	T1-T3	T2-T4	T5- C	T6- C	T7- C	T8- C	T5-T7	T6-T8
Measuring the base of the skull																									
NS	68.51 ±3.68	68.33 ±6.49	68.41 ±5.59	69.13 ±6.19	67.74 ±6.04	68.14 ±6.83	68.97 ±6.84	67.13 ±6.19	67.33 ±6.34	68.73 ±6.19	67.01 ±5.19	67.98 ±5.34	68.72 ±5.19												
S-BA	46.41 ±5.37	45.21 ±2.12	46.21 ±2.42	46.51 ±2.21	46.11 ±2.42	46.31 ±2.11	46.81±2.31	44.51 ±2.21	45.32 ±2.71	46.21 ±3.73	44.21 ±2.32	45.21 ±2.54	46.83 ±3.47												
N-Ba	106.7 ±2.63	105.6 ±9.41	105.9 ±8.71	106.2 ±8.82	105.1 ±8.21	106.3 ±7.34	106.9 ±8.37	106.5 ±8.41	106.9 ±6.72	106.9 ±8.41	105.1 ±8.21	106.3 ±7.82	106.8 ±7.32												
S-Ptm	45.53 ±3.89	45.64 ±4.49	45.67 ±4.57	46.34 ±4.29	46.43 ±5.39	46.73 ±5.72	46.92 ±5.79	44.34 ±4.59	45.31 ±4.84	45.94 ±4.73	44.64 ±4.39	45.52 ±6.21	45.74 ±5.21												
BaSN	134.8 ±3.76	132.4 ±4.39	133.4 ±4.33	135.3 ±3.71	133.1 ±5.09	134.3 ±5.93	134.7 ±6.27	133.3 ±3.21	134.4 ±4.71	134.9 ±5.34	131.4 ±4.29	133.2 ±5.13	134.5 ±3.72												
Measurement of the ratio of sagittal and vertical jaws																									
SNA	82.71 ±1.35	84.01 ±3.34	83.14 ±3.24	82.64 ±3.31	82.31 ±4.52	82.92 ±3.32	82.01 ±5.11	81.84 ±2.14	81.2 ±3.13	82.02 ±2.54	81.71 ±3.24	81.44 ±3.31	82.92 ±4.12												
SNB	80.25 ±0.14	76.5 ±1.21	80.12 ±1.31	80.89 ±1.52	75.1 ±1.31	80.34 ±1.25	80.52 ±1.74	74.8 ±2.19	79.51 ±3.29	80.25 ±1.74	74.1 ±1.91	80.19 ±1.33	80.58 ±1.34	*	*	*	*			*	*	*	*		
ANB	2.89 ±0.46	6.35 ±1.96	2.96 ±1.21	2.51 ±1.75	6.14 ±1.24	3.23 ±1.38	2.73 ±1.28	5.83 ±1.24	3.12 ±1.19	2.52 ±2.04	5.14 ±1.34	2.98 ±1.41	2.44 ±1.28	*	*	*	*			*	*	*	*		
PL to ML	23.87 ±1.41	23.79 ±4.23	25.6 ±3.22	25.89 ±2.41	24.19 ±4.11	30.4 ±4.21	31.2 ±5.47	24.12 ±3.79	25.21 ±3.21	26.4 ±5.11	23.79 ±3.31	29.89 ±2.41	30.8 ±4.75	*	*	*	*	*	*	*	*	*	*	*	*
FMA	32.38 ±4.25	32.16 ±4.31	34.28 ±4.12	34.71 ±4.22	31.42 ±3.34	38.85 ±3.34	39.4 ±5.31	30.96 ±3.41	32.99 ±3.21	33.4 ±5.45	31.21 ±3.53	37.71 ±4.22	39.7 ±6.34	*	*	*	*	*	*	*	*	*	*	*	*
NA-Pog	177.4 ±8.14	182.9 ±9.21	178.3 ±9.46	177.2 ±7.12	183.4 ±8.33	178.8 ±7.41	177.5 ±5.21	184.4 ±8.64	178.1 ±6.41	177.4 ±8.75	185.3 ±6.25	179.2 ±7.12	177.3 ±8.37	*	*	*	*			*	*	*	*		
SN-Pog	80.94 ±4.1	74.47 ±4.32	79.34 ±4.11	80.54 ±3.36	73.11 ±3.14	78.65 ±2.74	80.37 ±4.12	74.32 ±4.14	80.32 ±3.36	80.74 ±5.12	74.68 ±3.44	79.54 ±4.36	80.85 ±5.72	*	*	*	*			*	*	*	*		
Dentoalveolar changes																									
Upper 1 to palatal plane	103.2 ±4.36	114.4 ±7.25	104.2 ±8.32	103.8 ±5.78	113.1 ±6.94	107.2 ±7.19	103.8 ±5.86	93.74 ±6.41	102.4 ±7.14	103.7 ±4.47	92.47 ±6.14	96.34 ±7.74	97.8 ±4.39	*	*	*	*			*	*			*	*
Upper 1 to NA (°)	23.35 ±1.98	26.14 ±3.12	24.09 ±4.03	23.14 ±1.38	27.37 ±4.21	25.01 ±3.11	23.85 ±1.58	18.8 ±1.41	22.4 ±1.37	23.46 ±2.91	17.23 ±1.54	19.7 ±1.33	20.94 ±1.78	*	*	*	*			*	*			*	*
Upper 1 to NA (mm)	5.33 ±2.03	6.11 ±3.14	5.45 ±2.04	4.73 ±2.93	6.74 ±2.14	5.83 ±1.74	5.86 ±3.15	2.76 ±1.31	4.83 ±1.43	5.74 ±1.75	1.44 ±1.19	3.22 ±1.09	3.17 ±2.03	*	*	*	*			*	*			*	*
Lower 1 to NB (°)	25.61 ±2.74	21.47 ±2.78	25.14 ±3.04	25.91 ±2.54	24.77 ±2.76	24.81 ±1.98	25.51 ±2.71	21.11 ±2.65	24.86 ±2.17	24.94 ±3.57	21.39 ±2.88	25.5 ±1.31	25.83 ±2.74	*	*	*	*			*	*	*	*		
Lower 1 to NB)mm)	5.12 ±1.65	2.11 ±1.34	5.12 ±1.38	5.74 ±1.88	2.67 ±1.19	4.54 ±1.64	5.12 ±2.45	1.98 ±1.31	3.58 ±1.33	4.47 ±1.26	2.07 ±1.24	3.45 ±1.41	5.74 ±1.65	*	*	*	*			*	*	*	*		
Interincisal angle	132.5 ±7.36	139.1 ±7.21	133.7 ±8.45	132.5 ±7.95	140.3 ±8.33	134.2 ±9.15	133.1 ±6.26	124.6 ±6.35	132.4 ±6.14	133.7 ±7.78	123.7 ±7.14	128.8 ±8.31	129.8 ±6.85	*	*	*	*			*	*			*	*

Continuation Table 2

Cephalometric parameters	Control group (C) (n=30)	53 children with class II division I (I group)						51 children with class II division II (II group)						Comparison between groups											
		MFA (T1) (n=31)			TB (T2) (n=22)			MFA (T1) (n=31)			TB (T2) (n=22)														
	Mean ± SD	Before Mean ± SD	10-12 mo. (T1) Mean ± SD	12-16 mo. (T2) Mean ± SD	Before Mean ± SD	10-12 mo. (T3) Mean ± SD	12-16 mo. (T4) Mean ± SD	Before Mean ± SD	10-12 mo. (T5) Mean ± SD	12-16 mo. (T6) Mean ± SD	Before Mean ± SD	10-12 mo. (T7) Mean ± SD	12-16 mo. (T8) Mean ± SD	T1- C	T2- C	T3- C	T4- C	T1-T3	T2-T4	T5- C	T6- C	T7- C	T8- C	T5-T7	T6-T8
Dentoalveolar changes																									
Overjet	3.81 ±1.65	9.32 ±2.31	4.34 ±2.27	3.81 ±1.65	8.79 ±3.41	5.04 ±4.01	3.45 ±2.47	1.32 ±1.43	3.37 ±2.04	3.87 ±1.82	1.19 ±1.11	2.01 ±1.17	3.67 ±1.24	*	*	*	*			*	*	*	*		
Nasolabial angle	105.7 ±8.73	99.34 ±7.75	103.9 ±4.38	105.8 ±7.58	98.44 ±5.41	101.6 ±4.34	104.5 ±7.85	109.1 ±6.11	105.9 ±5.31	105.7 ±5.47	108.9 ±7.31	107.1 ±4.21	106.8 ±7.52	*	*	*	*			*	*			*	*
Labiomental angle	121.5 ±7.11	103.4 ±6.09	120.9 ±5.19	122.1 ±7.85	100.8 ±7.17	119.3 ±14.3	122.4 ±8.81	107.3 ±7.47	121.5 ±7.25	122.1 ±6.74	106.4 ±6.79	118.8 ±8.74	120.4 ±6.34	*	*	*	*			*	*	*	*		
Upper lip-E distance	-0.13 ±0.16	2.14 ±1.31	0.29 ±0.87	-0.14 ±0.19	2.09 ±1.24	0.52 ±0.21	-0.73 ±0.57	-1.89 ±1.04	-0.74 ±0.42	-0.18 ±0.16	-1.76 ±1.21	-0.92 ±0.32	-0.74 ±0.37	*	*	*	*			*	*			*	*
Lower lip-E distance	1.15 ±1.12	-0.5 ±0.39	1.38 ±0.41	1.16 ±1.32	-0.74 ±0.35	0.93 ±0.44	1.07 ±1.58	-4.71 ±2.52	0.92 ±2.11	1.08 ±1.57	-4.94 ±3.41	0.88 ±0.75	1.28 ±1.38	*	*	*	*			*	*	*	*		
Measurement of the hyoid bone																									
H- RGP-cv3ia	25.97 ±3.41	35.74 ±5.33	26.29 ±4.43	25.59 ±4.38	35.14 ±5.17	31.51 ±5.44	26.14 ±5.44	37.25 ±5.87	26.91 ±3.41	26.09 ±5.38	36.24 ±5.14	32.12 ±6.42	26.19 ±5.12	*	*		*	*		*	*		*	*	
RGP-cv3ia-H (H-H1)	5.34 ±2.14	14.06 ±3.09	5.95 ±3.12	5.15 ±3.82	15.14 ±5.33	10.38 ±4.12	7.47 ±5.21	14.37 ±5.45	6.73 ±3.18	5.85 ±4.93	14.91 ±4.41	11.25 ±3.19	5.82 ±2.97	*	*		*	*		*	*		*	*	
Measurement of the soft palate																									
Pns-P	32.74 ±2.14	38.26 ±3.84	33.84 ±3.12	32.47 ±5.15	37.11 ±3.14	35.36 ±4.58	32.64 ±4.24	37.21 ±4.04	32.11 ±4.25	31.26 ±4.22	37.31 ±3.31	35.14 ±3.11	32.41 ±4.21	*	*	*	*			*	*	*	*		
V-W	9.74 ±2.11	13.41 ±3.67	9.47 ±4.41	8.84 ±3.03	12.21 ±3.34	10.74 ±2.47	9.13 ±3.21	13.24 ±3.22	9.47 ±4.78	9.15 ±3.72	13.31 ±3.04	11.39 ±3.14	9.45 ±2.17	*	*	*	*			*	*	*	*		
The position of the cervical vertebrae																									
CVA	104.1 ±5.32	118 ±8.54	103.1 ±5.58	101.5 ±9.51	114 ±6.21	109.1 ±4.58	104.5 ±7.41	109 ±7.26	103.6 ±5.74	101.6 ±4.65	114 ±6.54	108.4 ±7.34	104.6 ±4.98	*	*		*	*		*	*		*	*	
OPT/CVT	1.21 ±1.47	4.39 ±1.51	1.58 ±1.47	1.14 ±1.02	4.49 ±1.41	3.21 ±2.17	1.51 ±1.02	3.91 ±1.23	1.56 ±2.41	1.44 ±1.21	3.49 ±1.63	2.41 ±1.12	1.28 ±2.67	*	*		*	*		*	*		*	*	
O-C1	6.44 ±2.34	2.14 ±3.44	6.28 ±3.12	6.55 ±3.12	2.04 ±1.23	4.44 ±2.34	6.69 ±3.12	1.73 ±1.02	5.78 ±3.52	6.18 ±1.25	1.94 ±1.23	3.15 ±1.24	5.18 ±3.36	*	*		*	*		*	*		*	*	
Measurement of the nasopharynx																									
Ba-Ptm	40.14 ±2.32	38.56 ±3.26	39.7 ±2.16	39.9 ±3.21	38.46 ±2.14	39.41 ±2.24	40.58 ±3.36	37.82 ±2.14	38.86 ±1.34	39.66 ±2.45	37.46 ±1.19	39.33 ±1.54	40.85 ±2.98												
Ba-PNS	43.11 ±2.32	41.62 ±3.81	42.7 ±3.14	43.4 ±2.52	40.92 ±1.41	41.78 ±2.21	43.85 ±3.57	40.21 ±1.11	41.13 ±2.11	42.93 ±3.71	39.92 ±1.61	41.86 ±1.21	43.16 ±1.36												
PNS-ppw	25.11 ±2.13	23.37 ±1.65	24.03 ±2.12	25.73 ±3.32	24.17 ±2.62	24.86 ±1.13	25.16 ±2.33	23.36 ±1.81	23.97 ±2.81	25.71 ±3.52	22.97 ±1.13	23.41 ±1.83	25.84 ±2.95												
Measurement of the oropharynx																									
P-MPW	13.14 ±1.31	8.81 ±2.06	13.12 ±2.25	14.08 ±2.14	8.34 ±2.85	11.48 ±2.14	11.48 ±2.14	8.27 ±2.18	13.18 ±3.25	13.28 ±2.28	8.13 ±2.14	10.6 ±2.32	13.17 ±3.27	*	*		*	*		*	*		*	*	
PPH-PH	9.91 ±1.93	5.33 ±1.64	8.54 ±2.98	9.34 ±1.95	5.24 ±1.22	7.11 ±1.34	8.95 ±2.36	4.82 ±1.31	8.69 ±2.94	9.31 ±1.25	4.24 ±1.02	5.92 ±1.41	9.37 ±2.34	*	*		*	*		*	*		*	*	
Measurement of the hypopharynx																									
Ep-LPW	18.31 ±1.32	12.48 ±2.08	18.03 ±1.54	18.49 ±2.25	12.38 ±2.11	14.95 ±2.74	17.99 ±3.58	11.88 ±2.19	17.99 ±2.74	18.49 ±3.83	12.18 ±2.75	15.37 ±2.42	17.79 ±3.31	*	*		*	*		*	*		*	*	

C: control group, MFA: Modified functional appliance, TB: Twin-block.

* p≤0.05 – the statistical significance in the differences of the differences of parameters

appliances showed improvement in their facial parameters, as evidenced by a decrease in the NA-Pog angle and an increase in the SN-Pog facial angle throughout all periods of treatment.

The fact that both groups exhibited these improvements suggests that both appliances were equally effective in correcting the malocclusions. Moreover, upon completion of the treatment, the facial parameters of both groups aligned with those of the control group, indicating successful normalization of the patients' facial parameters.

The study found that both the modified functional appliance and the twin-block were effective in reducing retrotrusion of upper incisors and improving the Upper 1 to palatal plane, Upper 1 to NA (°), and distance between Upper 1 to NA (mm) parameters in patients with class II division I malocclusions after 10-12 months of treatment. No significant difference was observed between the two appliances.

However, in patients with class II division II malocclusions, MFA treatment for 10-12 months resulted in a significant protrusion of the upper incisors, as well as an increase in the Upper 1 to palatal plane, Upper 1 to NA (°), and distance Upper 1 to NA (mm) parameters. Meanwhile, the twin-block appliance showed only a minor increase in these parameters after both 10-12 and 12-16 months of treatment. The study also observed significant statistical differences between the two appliances during the 10-12 and 12-16 months of treatment in class II division II.

The study found that the modified functional appliance (MFA) was more effective than the twin-block appliance in correcting the inclination of anterior teeth in patients with class II division II malocclusions. This is likely due to the design features of the MFA, which includes a protraction arch that is specifically designed to correct the inclination of incisors.

In contrast, when using a twin-block appliance, additional bracket fixation is typically needed to correct the inclination of incisors after functional orthopedic treatment in patients with class II division II, which can make the treatment process more complicated and time-consuming.

Therefore, the MFA may be a more efficient and effective option for treating patients with class II division II malocclusions who require correction of anterior tooth inclination.

After undergoing treatment for 10-12 months with either appliance, both groups exhibited normalization of the Lower 1 to NB angles (°) and Lower 1 to NB distances (mm). These findings suggest that there was no discernible difference in the effectiveness of the two appliances. Both appliances were able to stimulate mandibular growth, resulting in the forward movement of the lower incisors.

The treatment resulted in significant changes in various parameters. In both appliance groups, Upper 1 to palatal plane, Upper 1 to NA (°), Upper 1 to NA (mm), and Interincisal angle (°) values decreased in class II division I and increased in class II division II. Moreover, in all treatment groups that used either appliance, the Lower 1 to NB (°) and Lower 1 to NB (mm) values increased, indicating the impact of the appliances on the dentoalveolar structure.

Over a period of 10-12 months, both appliances were found to increase the nasolabial angle and decrease the distance between the E line and upper lip in class II division I. A slight increase was also noted after 12-16 months of treatment, but there were no significant differences between the two appliances during the different periods of treatment. In contrast, in class II division II, a modified functional appliance resulted in a decrease in the nasolabial angle after 10-12 months of treatment, with a further slight decrease noted after 12-16 months of treatment. However, during both 10-12 months and 12-16 months of treatment with Twin block, a slight decrease was observed. The differences between the two appliances were statistically significant during different periods of treatment for class II division II, which can be attributed to the modified functional appliance's design features, including a protraction arch that corrects the inclination of anterior teeth in patients with class II division II.

In addition, during the 10-12 month period, both groups using either appliance showed an increase in the labiomental angle and a decrease in the distance between the E line and lower lip. There were no significant differences between the two appliances, indicating that both appliances were effective in improving the appearance of the lower third of the face.

In both class II division I and II, the hyoid bone angle decreased after 10-12 months of modified functional appliance (MFA) treatment, and the parameters were restored to normal levels within the designated timeframe. A minor reduction in the hyoid bone angle was observed during treatment with Twin block (TB), and the parameters approached the values of the control group only after 12-16 months.

Throughout the treatment period, the H-H1 distance decreased, with the MFA showing greater effectiveness from 10-12 months of treatment compared to TB, which showed effectiveness only after 12-16 months of treatment. Both appliances have an inclined plane that stimulates the growth of the mandible forward, leading to the elevation of the hyoid bone. However, the wavy bar in the MFA promotes the movement of the hyoid bone in the antero-superior direction, leading to the forward movement of the tongue and the normalization of tongue position. As a result, the hyoid bone moves in the antero-superior direction faster with the MFA than with TB.

During treatment, both the Modified Functional Appliance (MFA) and Twin Block (TB) groups showed significant improvements in the PNS-P distance and the thickness of the soft palate V-W (mm) compared to the control group. However, there were no statistically significant differences between the two appliances during any of the treatment periods (T1-T3, T2-T4, T5-T7, T6-T8). These findings suggest that both appliances were effective in normalizing the length and thickness of the soft palate, which could contribute to the expansion of the narrowed upper airway in Class II malocclusion.

The results indicate that both groups exhibited a decrease in CVA and OPT/CVT angle and an increase in OA distance after treatment, suggesting anterior rotation of the head and cervical vertebrae. However, the modified functional appliance group showed a significant reversal of these parameters towards normal levels after 10-12 months of treatment, while the TB group demonstrated only a slight decrease in CVA and OPT/CVT angle and an increase in OA distance, which gradually approached normal levels after 12-16 months of treatment.

The anterior rotation of the head and cervical vertebrae observed in both groups resulted in an increase in the distance between the cervical vertebrae and the mandible, which led to a significant expansion of the upper airway following functional orthopedic treatment. The improvement in the upper airway was associated with the forward growth of the mandible, which was particularly evident in the first subgroup of both groups that received the modified functional appliance.

The study found that the measurements of the nasopharynx, specifically the Ba-Ptm, Ba-PNS, and PNS-ppw, did not show significant changes in either group compared to the control group during all follow-up periods. The present study has yielded a noteworthy observation, indicating a tenuous association between the nasopharyngeal and mandibular position with normal nasal function. These findings are in alignment with the existing corpus of literature on this subject matter [29].

The study's results demonstrate that both the modified functional appliance and twin block appliance were effective in increasing oropharyngeal measurements in children with class II malocclusion. However, patients treated with the modified functional appliance achieved a return to normal parameters more quickly, within 10-12 months, compared to 12-16 months with the twin block appliance (T1-T3, T5-T7). The hypopharynx measurement (Ep-LPW) also showed a similar pattern during the study.

The inclusion of a wavy bar in the modified functional appliance was found to be a contributing factor to its effectiveness in normalizing the size of the oropharynx and hypopharynx. This feature facilitates movement of the hyoid bone in an anterior-superior direction, which helps normalize its position and encourages proper movement of the tongue and rest tongue into a physiological position. This results in forward head posture, cervical vertebrae adaptation, and correction of anterior teeth inclination (in patients with class II division II, thanks to the protraction arch). Moreover, the inclined plane in the modified functional appliance promotes forward mandibular growth.

Conclusions. Both functional orthodontic appliances were highly effective in treating skeletal class II malocclusion. Based on the cephalometric measurements, the proposed modified functional appliance offers the following advantages:

1. The protraction arch in the modified functional appliance exerts a forward force on the maxillary anterior teeth, helping to correct their inclination and position. This results in faster normalization of cephalometric measurements such as angles Upper 1 to palatal plane, Upper 1 to NA (°), and distance Upper 1 to NA (mm) in patients with class II division II malocclusion, compared to the twin-block appliance.
2. Faster normalization of nasolabial angle values in patients using the modified functional appliance compared to the twin-block appliance.
3. The wavy bar in the modified functional appliance is specifically designed to encourage anterosuperior movement of the hyoid bone and promote forward movement of the tongue, which can help correct the issues associated with class II malocclusion. By stimulating the muscles of the tongue and hyoid bone, the wavy bar can lead to faster normalization of the H-H1 distance and angle of the hyoid bone compared to the twin-block appliance, which does not have a specific mechanism for encouraging this type of movement.
4. Results of the study revealed that the use of the modified functional appliance resulted in a

more rapid normalization of the CVA, reduction of the OPT/CVT angle, and an increase in the OA distance compared to the twin-block appliance. These findings can be attributed to the unique design of the modified functional appliance, which promotes forward rotation of the head and cervical vertebrae, leading to increased distance between the mandible and cervical vertebrae and significant expansion of the upper airway.

5. The results of the study suggest that changes in the mandibular position induced by the modified functional appliance or the twin-block appliance do not have a significant impact on the measurements of the nasopharynx, including the Ba-Ptm, Ba-PNS, and PNS-ppw. These findings indicate a weak or insignificant correlation between the nasopharyngeal and mandibular position with normal nasal function.

6. The study findings suggest that the use of the modified functional appliance may result in a more rapid normalization of the oropharynx and hypopharynx measurements compared to the twin-block appliance. This could be attributed to the presence of a wavy bar in the modified functional appliance, which directs the hyoid bone anterosuperiorly, and promotes forward head posture. Additionally, the use of a protraction arch in patients with Class II Division II malocclusion helps to correct the inclination of anterior teeth and promote the growth of the mandible through the inclined plane.

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