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Effects of Three Types of Functional Appliances in Class II Malocclusions Treatment – Sagittal and Vertical Changes

Терапијски ефекти три врсте функционалних апарата у лечењу малоклузија II скелетне класе – сагиталне и вертикалне промене

SUMMARY

Introduction/Objective Class II malocclusions are sagittal malocclusions characterized by a distal relationship of posterior teeth. Depending on the underlying problem, class II can be skeletal or dento-alveolar. Class II treatment modality will depend on the cause, severity and age. Growth modification is the best treatment option in skeletal Class II growing patients.

The aim of this study was to establish and compare sagittal and vertical skeletal and dental changes in patients treated with the "M block" appliance, the Fränkel functional regulator and the Balters' Bionator.

Methods The sample consisted of 70 patients diagnosed with skeletal class II (ANB > 4°) and mandibular retrognathism (SNB < 80°). Patients were divided into 3 groups according to the type of appliance. All patients went through the standard diagnostic procedure (anamnesis, clinical and functional analysis, study model, panoramic radiograph and cephalometric analysis) and dental and skeletal age was determined. Treatment effects were analyzed on study models and cephalograms at the end of treatment.

Results All appliances led to significant mandibular anterior movement and sagittal growth, which reduced ANB values. All three groups of patients presented with neutral growth pattern, upper incisor retrusion and lower incisor protrusion at the end of treatment.

Conclusion Results of this study indicate efficacy of all three appliances in skeletal class II treatment.

Keywords: Class II malocclusion; Functional treatment; "M block" appliance; Fränkel appliance; Bionator

САЖЕТАК

Увод/Циљ Малоклузије II класе су сагиталне неправилности загрижаја које карактерише дистални однос бочних зуба. Зависно које структуре су у неправилном односу, деле се на скелетне и дентоалвеоларне. Терапија II класе зависи од узрока, изражености и узраста. Најбољи вид терапије уколико пацијенти и даље расту је модификација раста.

Циљ ове студије био је да се утврде и упореде сагиталне и вертикалне промене на скелетним и денталним структурама у току лечења М блок-апаратом, Френкловим регулатором функције тип I и бионатором по Балтерсу тип I.

Методе рада 70 испитаника са дијагнозом скелетног дисталног загрижаја (АНБ>4°) и мандибуларног ретрогнатизма (СНБ<80°), према врсти апарата, подељени су у три групе. Сви су прошли кроз стандардну дијагностику (анамнеза, клиничка и функционална анализа, анализа студијских модела, ортопантомографског и профилног телерендгенског снимка). Терапијски ефекти и промене анализирани су на студијским моделима и профилном снимцима по завршетку терапије.

Резултати Сва три апарата довела су до значајног мезијалног усмеравања и сагиталног раста мандибуле, што је смањило АНБ угао. У све три групе је утврђен неутрални раст, као и ретрузија горњих и протрузија доњих секутића.

Закључак Резултати студије указују на ефикасност сва три испитивана апарата у лечењу скелетних малоклузија II класе.

Кључне речи: Малоклузије II класе; М блок; Функционална терапија; Френклов апарат; Бионатор

INTRODUCTION

Class II malocclusions are sagittal malocclusions characterized by a distal relationship of posterior teeth. Depending on the underlying problem, class II can be skeletal or dento-alveolar. Skeletal class II is characterized by a distal maxillo-mandibular relationship. This could be a consequence of mandibular retrognathism and/or underdeveloped mandible, maxillary prognathism and/or overdeveloped maxilla, or a combination of the two [1, 2]. Depending on the cause of the malocclusion, class II can be treated by growth modification, dental camouflage, or orthodontic-surgical treatment. Whenever there is a skeletal discrepancy, best treatment option would be growth modification. However, this treatment modality could be used only if the patient is still growing [3, 4]. Growth modification treatment uses patient's residual growth in order to change jaw dimensions

and position and establish proper occlusion. Ideal timing for this kind of treatment would be right before the pubertal growth spurt. Removable functional appliances are the most commonly used appliances in children and late-mixed dentition adolescents. Fixed functional appliances are commonly used in adolescents and permanent dentition post-adolescents, due to limited effects of removable appliances and lack of compliance [4].

Growth modifying functional appliances facilitate change in the activity of different groups of muscles by delivering forces to the jaws and teeth, therefore affecting their function and position.[5] Most commonly used functional appliances are Andresen Activator, Twin Block appliance, Sander's "Bite Jumping" appliance, Fränkel functional regulator, Balters' Bionator, etc. A modification of the Sander's "Bite Jumping" appliance made with the Schaneng screw (Dentaurum) instead of the Sander's functional screw (Forestadent) has been successfully used at the Department of Orthodontics University of Belgrade for over a decade. This appliance, also known locally (in Serbia) by the name "M block" appliance, consists of an upper and lower removable appliance. An expansion screw and the Schaneng functional screw are built into the upper appliance. The lower appliance contains an inclined plane that guides the functional screw and directs the mandible forward. The "M block" appliance (Figure 1) is built according to the design suggested by Sander for his "Bite Jumping" appliance [6, 7].

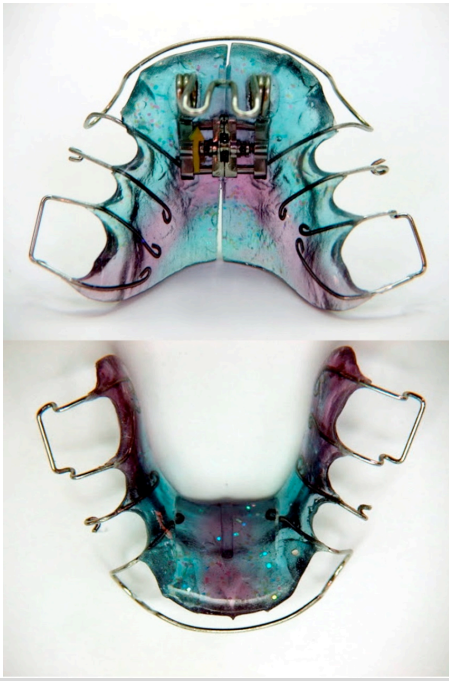

Figure 1. "M block" appliance.

Figure 2. Fränkel functional regulator type I.

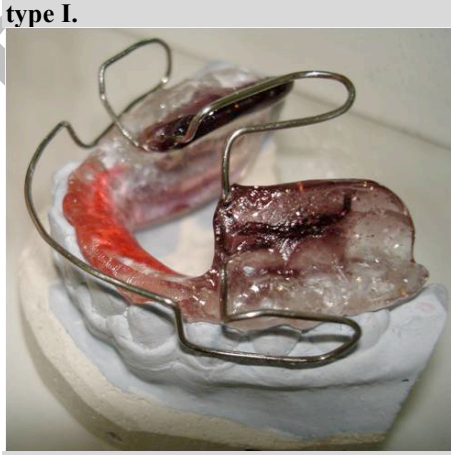

Figure 3. Balters' Bionator type I.

The aim of this study was to establish and compare sagittal and vertical skeletal and dental changes in patients treated with the "M block" appliance, the Fränkel functional regulator (Figure 2) and the Balters' Bionator (Figure 3).

METHODS

The sample of this study consisted of 70 patients treated at the Department of Orthodontics Faculty of Dental Medicine University of Belgrade. Inclusion criteria were skeletal distal bite (ANB > 4°), mandibular retrognathism (SNB < 80°), no previous orthodontic treatment and appropriate age (pre pubertal growth spurt).

According to the type of appliance used in treatment, subjects were divided into three groups: Group I: Patients treated with the "M block" appliance (30 subjects); Group II: Patients treated with the Fränkel functional regulator type I (20 subjects); Group III: Patients treated with the Balters' Bionator type I (20 subjects).

All three appliances are indicated for treating growing patients diagnosed with skeletal distal bite and mandibular retrognathism.

Standard diagnostic procedure was performed, which included anamnesis, clinical and functional examination, study model analysis, panoramic radiograph analysis and cephalometric analysis. Dental age was estimated according to the Demirjian's method [8]. Skeletal age was determined using the modified CVM (Cervical Vertebral Maturation) method described by Baccetti [9]. According to age assessment, all patients were in the pre-pubertal growth spurt period, which is a crucial prerequisite for functional orthodontic treatment. The average chronological age of patients before the beginning of treatment was 10 years and 1 month, and the average dental age was 9 years and 5 months. Skeletal age analysis of pretreatment records revealed the following data: In group I, 3 patients were in stage 1 (10%), 22 patients in stage 2 (73%) and 5 patients in stage 3 (17%); In group II, 9 patients were in stage 1 (45%), 7 patients in stage 2 (35%) and 4 patients in stage 3 (20%); In group III, 4 patients were in stage 1 (20%), 9 patients in stage 2 (45%) and 7 patients in stage 3 (35%). Average treatment time was 15 months in group I, 20 months in group II and 22 months in group III. Patients' age, treatment time and gender distribution are shown in table 1.

Table 1. Age, treatment time and gender distribution.

	Mean age (years, months)		Skeletal age	Treatment time	Gender	
	chronological	dental		(months)	♂	♀
M block n=30	10 y 4 m	9 y 8 m	Stage 1 (10%) Stage 2 (73%) Stage 3 (17%)	15	13	17
Fränkel n=20	8 y 8 m	9 y 2 m	Stage 1 (45%) Stage 2 (35%) Stage 3 (20%)	20	10	10
Bionator n=20	10 y 7 m	9 y 3 m	Stage 1 (20%) Stage 2 (45%) Stage 3 (35%)	22	9	11

Cephalometric analysis

The following cephalometric parameters were used: I Sagittal parameters (angles): SNA – sagittal position of the maxilla, SNB – sagittal position of the mandible, SNPg – sagittal position of the chin, ANB – sagittal maxillo-mandibular relationship; II Maxillary and mandibular development parameters (linear distances): Snp to A' – length of the maxillary corpus (C max), Go' to Pg' – length of the mandibular corpus (C mand), Cd' to Go' – length of the mandibular ramus (R mand), Cd to Me – total mandibular length (Mand); III Vertical parameters (angles): SN/SpP – vertical position of the maxilla, SN/MP – vertical position of the mandible, SpP/MP – vertical maxillo-mandibular

relationship; IV Type of growth: Bjork polygon (Σ= NSAr+SArGo+ArGoMe), Anterior to posterior facial height relation (S-Go/N-Me x 100); V Incisor position (angles): I/SpP – upper incisor inclination, i/MP – lower incisor inclination.

All appliances ("M block", Fränkel functional regulator type I and Balters' Bionator type I) were made according to standard principles previously described in literature [10]. Therapeutic effects of these appliances and consequential changes were recorded on study models and cephalograms at the end of treatment.

Statistical analysis

Mean values, standard deviations, minimal and maximal values were calculated as a part of descriptive statistics. Statistical analysis included two-factor analysis of the variance with repeated measuring, where the measuring was done in relation to the factor time and the time and group allocation factor. Mono-factorial variance analysis was done using the ANOVA, Boneferroni and Student's t-test for determining statistical significance of acquired differences.

This research was approved by the Ethical Committee of the Faculty of Dental Medicine University of Belgrade (resolution number 36/6 issued on 21 March 2012.).

RESULTS

I Sagittal parameters

The SNA angle decreased slightly after the "M block" appliance and Fränkel functional regulator treatment, and increased significantly after Bionator treatment. Two-factor analysis of the variance with repeated measuring was used to evaluate the treatment effect of three different functional appliances on the sagittal position of the maxilla in two different time periods (beginning and end of treatment) and it was established that there were no statistically significant changes in pre- and post-treatment values. However, statistically significant changes appeared when all three appliances were compared. The SNB angle increased significantly in all three groups of patients. Two-factor analysis of the variance with repeated measuring revealed the influence of time on the SNB value changes within groups. Statistically significant difference was also noted when comparing all three appliances over time. The SNPg angle also increased significantly after treatment in all three groups. Two-factor analysis of the variance with repeated measuring showed the influence of time on the value changes before and after treatment, as well as between groups over time (Table 2). The ANB angle decreased significantly in all three groups. Statistically significant differences were noted in the pre-treatment values of parameters between group I and group II and in the post-treatment values of parameters between group I and group II, and group II and group III (Table 3).

II Maxillary and mandibular development parameters

Maxillary corpus length increased significantly after treatment in all three groups. Two-factor analysis of the variance with repeated measuring established a statistically significant change in the

Table 2. Values and statistical significance of changes – sagittal parameters SNA, SNB and SNPg.

	T1 x ± SD	T2 x̄ ± SD	Δ (T2 - T1) x̄ ± SD	Significance[a] (difference between groups at T1)	Significance[a] (difference between groups at T2)	Significance[b/c]	Significance[d]
SNA (°)					*p*		
M block n=30	81.72 ± 2.97	81.63 ± 3.45	-0.08 ± 1.26				0.720
Fränkel n=20	81.4 ± 2.52	81.25 ± 2.49	-0.15 ± 1.14	0.876	0.357	[b]0.075 [c]0.005*	0.562
Bionator n=20	81.35 ± 2.66	82.55 ± 2.48	1.20 ± 1.96				0.013*
SNB (°)							
M block n=30	76.35 ± 3.22	77.48 ± 3.13	1.13 ± 1.40				0.000*
Fränkel n=20	74.7 ± 2.56	77.65 ± 2.46	2.95 ± 1.05	0.148	0.971	[b]0.000* [c]0.000*	0.000*
Bionator n=20	75.5 ± 2.72	77.65 ± 2.68	2.15 ± 1.34				0.000*
SNPg (°)							
M block n=30	77.6 ± 2.79	78.56 ± 2.86	0.96 ± 0.99				0.000*
Fränkel n=20	76.5 ± 2.44	78.55 ± 2.64	2.05 ± 0.99	0.250	0.857	[b]0.000* [c]0.001*	0.000*
Bionator n=20	76.5 ± 2.84	78.15 ± 2.70	1.65 ± 0.87				0.000*

[a]Mono-factorial variance analysis; [b]Two-factor analysis of the variance, factor time; [c]Two-factor analysis of the variance, factor time*group; [d]t-test for paired samples

Table 3. Values and statistical significance of changes – sagittal parameter ANB.

ANB (°)	T1	T2	significance[a] (difference between groups at T1)	significance[a] (difference between groups at T2)	significance[b] (difference between groups at T1)	significance[b] (difference between groups at T2)	significance[c] (difference within groups T1 and T2)
					p		
M block n=30	5.5±0.81	4.38±1.11			0.001 M vs F	0.005 M vs F	0.000
Fränkel n=20	6.6±1.35	3.6 ± 1.23	0.005	0.002	0.114 M vs B	0.154 M vs B	0.000
Bionator n=20	5.9±1.07	4.9 ± 1.23			0.086 F vs B	0.002 F vs B	0.004

[a] Kruskal-Wallis Test; [b] Mann-Whitney Test; [c] Wilcoxon Test od equivalent pairs

pre- and post-treatment values of the maxillary corpus length. Statistically significant changes were also noted when comparing all three groups of treated patients. Mandibular corpus increased significantly after "M block" appliance and Fränkel functional regulator treatment, while an insignificant change was established after Bionator treatment. Two-factor analysis of the variance with repeated measuring revealed statistically significant influence of mandibular corpus length change within groups over time. Mandibular ramus height increased significantly in all three groups of patients. Two-factor analysis of the variance with repeated measuring revealed the influence of mandibular ramus length value changes within groups over time. Total mandibular length increased statistically in all three groups. Two-factor analysis of the variance with repeated measuring showed a

statistically significant influence of total mandibular length change within groups before and after treatment (Table 4).

Table 4. Values and statistical significance of maxillary and mandibular development parameters.

	T1	T2	Δ (T2 - T1)	significance[a] (difference between groups at T1)	significance[a] (difference between groups at T2)	significance [b/c]	significance [d]
C max (mm)							
M block n=30	48.57±3.28	49.80±3.13	1.23±0.72				0.000
Fränkel n=20	49.30±2.34	50.80±2.39	1.50±1.36	0.596	0.100	[b]0.000 [c]0.011	0.000
Bionator n=20	49.23±2.50	51.60±2.98	2.37±1.83				0.000
C mand (mm)							
M block n=30	70.33±5.37	72.02±5.23	1.69±0.85				0.000
Fränkel n=20	71.23±5.32	73.20±4.72	1.97±1.40	0.829	0.690	[b]0.000 [c]0.168	0.000
Bionator n=20	71.08±6.09	72.05±5.35	0.97±2.69				0.122
R mand (mm)							
M block n=30	55.77±3.63	57.50±3.88	1.73±0.93				0.000
Fränkel n=20	55.10±4.08	56.55 ± 3.43	1.45±2.96	0.515	0.537	[b]0.000 [c]0.796	0.041
Bionator n=20	54.47±4.09	56.45 ± 3.71	1.98±3.33				0.016
Mand (mm)							
M block n=30	108.02±5.72	109.80±5.78	1.78±1.27				0.000
Fränkel n=20	105.70±5.16	108.40±5.11	2.70±3.21	0.212	0.442	[b]0.000 [c]0.320	0.001
Bionator n=20	107.75±2.72	110.50±3.28	2.75±3.15				0.003

[a]Mono-factorial variance analysis; [b]Two-factor analysis of the variance, factor time; [c]Two-factor analysis of the variance, factor time*group; [d]t-test for paired samples.

III Vertical parameters

The SN/SpP angle increased significantly after "M block" appliance treatment, and insignificantly after Fränkel functional regulator and Bionator treatment. Two-factor analysis of the variance with repeated measuring established a statistically significant difference in value changes before and after treatment, and a lack of significance when comparing all three groups before and after treatment. The SN/MP angle decreased insignificantly in group II, while it increased significantly in groups I and III. Mono-factorial variance analysis revealed statistically significant differences between groups I and III before treatment. Statistically significant differences were also noted when comparing groups after treatment. Two-factor analysis of the variance with repeated measuring established a statistically significant influence of value changes before and after treatment, as well as between groups over time. Fränkel functional regulator treatment resulted in a decrease of the SpP/MP angle, while the "M block" and Bionator treatment resulted in an increase of the same angle. Statistically significant changes were present when comparing post-treatment values between

groups, while comparing groups in pairs lacked significance. Two-factor analysis of the variance with repeated measuring revealed statistically significant differences between groups over time (Table 5).

Table 5. Values and statistical significance of vertical parameters SN/SpP, SN/MP, SpP/MP.

	T1 $\bar{x} \pm SD$	T2 $\bar{x} \pm SD$	Δ (T2 - T1) $\bar{x} \pm SD$	significance[a] (difference between groups at T1)	significance[a] (difference between groups at T2)	significance[b/c]	significance[d]	significance[e] (difference between groups at T1)	significance[e] (difference between groups at T2)
SN/SpP (°)									
M block n=30	8.25±4.39	9.10±4.92	0.85±1.32				0.001		
Fränkel n=20	8.90±2.12	9.30±2.13	0.40±1.90	0.567	0.704	[b]0.001 [c]0.616	0.359		
Bionator n=20	9.30±3.03	10.00±2.96	0.70±1.59				0.064		
SN/MP (°)									
M block n=30	31.60±5.56	32.50±6.10	0.90±2.20				0.033 *	0.437 M vs F	1.00 M vs F
Fränkel n=20	33.85±4.97	33.08±5.31	-0.77±2.29	0.021	0.004*	[b]0.033 [c]0.005	0.261	0.018 M vs B	0.005 MvsB
Bionator n=20	35.95±5.19	37.85±5.16	1.90±2.53				0.003	0.642 F vs B	0.027 FvsB
SpP/MP(°)									
M block n=30	26.58±5.12	27.17±4.79	0.59±1.96				0.115		0.10 M vs F
Fränkel n=20	25.10±5.61	23.90±5.07	-1.20±3.03	0.608	0.039	[b]0.505 [c]0.017	0.930		1.00 M vs B
Bionator n=20	26.55±6.10	27.85±5.91	1.30±3.51				0.114		0.058 F vs B

[a]Mono-factorial variance analysis; [b]Two-factor analysis of the variance, factor time; [c]Two-factor analysis of the variance, factor time*group; [d]t-test for paired samples; [e]Bonferroni test

IV Type of growth parameters

The sum of the Björk polygon angles increased in all groups, the Bionator group lacking statistical significance. Two-factor analysis of the variance with repeated measuring recognized the influence of all three types of appliances on the increase at two points in time (before and after treatment). There was no significant interaction between the type of appliance and time, while a significant influence of time (before and after treatment) was confirmed in patients within each group. The percentage of the anterior to posterior facial height relation decreased, but none of the appliances caused any statistically significant differences in the pre- and post-treatment values (Table 6).

Table 6. Values and statistical significance of the type of facial growth parameters.

	T1 $\bar{x} \pm SD$	T2 $\bar{x} \pm SD$	Δ (T2 - T1) $\bar{x} \pm SD$	significance[a] (difference between groups at T1)	significance[a] (difference between groups at T2)	significance[b/c]	significance[d]
Σ Bjørk (°)							
M block n=30	393.50±4.68	395.80 ± 3.39	2.30 ± 3.51				0.001
Fränkel n=20	393.55±5.34	395.70 ± 4.17	2.15 ± 2.66	0.733	0.901	[b]0.000 [c]0.313	0.002
Bionator n=20	394.60±5.67	395.35 ± 2.72	0.75 ± 4.66				0.481
S-Go/N-Me x 100 (%)							
M block n=30	65.05±3.78	65.14 ± 3.50	0.09 ± 1.34				0.711
Fränkel n=20	65.31±3.17	65.05 ± 3.07	-0.26 ± 1.70	0.590	0.384	[b]0.441 [c]0.656	0.505
Bionator n=20	64.15±4.28	63.83 ± 3.77	-0.32 ± 2.23				0.524

[a]Mono-factorial variance analysis; [b]Two-factor analysis of the variance, factor time; [c]Two-factor analysis of the variance, factor time*group; [d]t-test for paired samples.

V Incisor position

Upper incisors were uprighted significantly after treatment in all three groups. Mono-factorial variance analysis revealed statistically significant changes in the I/SpP angle after treatment, as well as between groups over time. Lower incisors were proclined significantly after "M block" and Fränkel functional regulator treatment, while the Bionator group lacked statistical significance. Mono-factorial variance analysis showed statistically significant differences between groups before treatment, while in post-treatment records significance appeared when comparing the "M block" appliance with the Fränkel functional regulator, and the "M block" appliance with the Bionator. Two-factor analysis of the variance with repeated measuring recognized statistically significant changes in the i/MP values after treatment, as well as significant differences between groups over time (Table 7).

Table 7. Values and statistical significance of the incisor position parameters.

	T1 $\bar{x}$± SD	T2 $\bar{x}$ ± SD	Δ (T2 - T1) $\bar{x}$ ± SD	Significance[a] (difference between groups T1)	Significance[a] (difference between groups T2)	Significance[b/c]	significance[d]	Significance[e] (difference between groups T1)	Significance[e] (difference between groups T2)
I/SpP (°)									
M block n=30	66.83±4.13	71.33±3.71	4.50±2.27				0.000	0.008 MvsF	
Fränkel n=20	70.10±2.98	70.90±3.07	0.80±1.23	0.006	0.904	[b]0.000 [c]0.000	0.009	0.059 MvsB	
Bionator n=20	69.35±3.43	71.15±3.01	1.80±1.23				0.000	1.000 FvsB	
i/MP (°)									
M block n=30	87.15±4.34	85.76±3.77	-1.38±1.91				0.000	0.041 MvsF	0.016 MvsF
Fränkel n=20	89.75±2.81	88.30±2.53	-1.45±1.27	0.029	0.001	[b]0.000 [c]0.013	0.000	0.166 MvsB	0.001 MvsB
Bionator n=20	89.15 ± 2.79	89.00 ± 2.17	-0.15±1.23				0.591	1.000 FvsB	1.000 FvsB

[a]Mono-factorial variance analysis; [b]Two-factor analysis of the variance, factor time; [c]Two-factor analysis of the variance, factor time*group; [d]t-test for paired samples; [e]Bonferroni test.

DISCUSSION

Growth modification treatment improves jaw relations, resulting in a positive effect on dental structures' relations. Changes that happen during the functional appliance treatment are a result of the synergy between the appliance effects and growth that would happen regardless of treatment. The aim of this study was to determine and compare sagittal and vertical changes that occurred during the "M block" appliance, Fränkel functional regulator type I and Balters' Bionator type I treatment. Patients diagnosed with skeletal distal bite caused by mandibular prognathism and in the pre-pubertal growth spurt period treated at the Department of Orthodontics Faculty of Dental Medicine University of Belgrade were involved in this research. Patients were divided into three groups according to the type of appliance used: Group I treated with the "M block" appliance, group II treated with the Fränkel functional regulator and group III treated with the Balters' Bionator. This was done in order to compare the effects of different types of functional appliances used in class II treatment.

Our results indicate an insignificant decrease in the SNA angle after "M block" and Fränkel functional regulator treatment, and a significant increase after Bionator treatment. SNB and SNPg

angles increased significantly in all three groups. All this resulted in the ANB angle decrease. Mandibular advancement with or without SNA angle decrease is a quintessential part of functional appliance treatment. As stated previously, "M block" appliance construction and treatment principles are similar to those of the Sander's appliance. Sander [7, 11] reported mesial mandibular movement and maxillary growth inhibition (similar to the high-pull headgear effect) as results of his "Bite Jumping" appliance treatment and stressed that this kind of maxillary response could only be achieved with one other appliance – the Herbst appliance. Decrease in the SNA angle after Bionator treatment was noted by Moreira Melo et al. [12], while Almeida et al. [13] found no differences between the Bionator treated group and the control group. Almeida et al. [13] also found significant increase in the SNB angle after Bionator treatment. Comparing patients treated with the Sander appliance and untreated class II controls, Sander and Wichelhaus [6] established significant increase of the SNB angle in treated patients. Comparing the "Bite Jumping" appliance, Fränkel functional regulator and Bionator treated patients, Sander and Lassak [14] found significantly greater skeletal effects after "Bite Jumping" appliance treatment, that led to mesial mandibular movement, maxillary growth inhibition and ANB angle decrease.

The fundamental question "Do functional orthodontic appliances stimulate additional mandibular growth?" still remains unanswered. Results obtained in this study indicate an increase in the length of maxillary and mandibular bodies in all three groups, regardless of the type of appliance used. Total mandibular length increased significantly after "M block" and Fränkel functional regulator treatment, while the Bionator group lacked significance.

In their meta-analysis from 2006, Cozza et al. [15] analyzed papers dealing with mandibular changes after functional class II treatment. In more than half of the papers analyzed, researchers had found clinically significant mandibular growth as a result of functional appliance treatment, and this growth was significantly greater if patients were treated at an appropriate age, i.e. during the pubertal growth spurt. However, none of the randomized clinical studies established clinically significant growth as a result of functional appliance treatment. This is in line with the finding of dos Santos-Pinto et al. [16] who have compared Bionator treated patients with untreated controls and found significant growth in both groups, regardless of whether they were treated or not. On the other hand Morreira Melo et al. [12] found an increase in total mandibular growth after Bionator treatment, which was confirmed by Almeida et al. [13] who reported significant increase in the length of mandibular corpus and total mandibular length. Class II functional treatment using the Bionator was also examined by Malta et al. [17] who found favorable skeletal and dental changes at the end of treatment, specifically significant increase in mandibular corpus length. Martina et al. [18] reported significant improvement in sagittal inter-maxillary relations after "Bite Jumping" appliance treatment, primarily due to the actual increase in mandibular corpus length and minimal maxillary growth restriction. Freeman et al. [19] examined the effects of the Fränkel functional regulator and found the greatest long-term effects had been achieved at the level of sagittal maxillo-mandibular relations, with

minimal maxillary growth inhibition. In their meta-analysis Perillo et al. [20] analyzed studies that examined the effects of the Fränkel functional regulator. Even though the research included was very heterogeneous, all authors stressed the positive effect of the Fränkel functional regulator on mandibular growth, especially total mandibular length, clinical effect reported being minimal to moderate. Another meta-analysis by Marisco et al. [21] analyzed the therapeutic effects of the Fränkel functional regulator, Bionator and several other functional appliances. All authors of included studies reported statistical significance of skeletal changes, but stated lack of their clinical significance. Even though this supports the claims that two-phase treatment has no advantages over one-phase treatment, Marisco et al. [21] stress the benefits of using functional appliances in the first phase of Class II treatment. Some of the advantages they mention are prevention of maxillary incisor trauma due to increased overjet, interception of dysfunction, psycho-social benefits for the growing child, stable dento-alveolar correction and shorter treatment time with fixed orthodontic appliances.

Looking at vertical parameters, results of our study indicate an increase after "M block" and Bionator treatment, while Fränkel functional regulator resulted in insignificant clockwise rotation of the maxilla and counter-clockwise rotation of the mandible. This led to a decrease in the maxillo-mandibular vertical angle after Fränkel functional regulator, and its increase after "M block" and Bionator treatment. The Björk-Jaraback analyses revealed neutral growth in all groups at the end of treatment.

Malta et al. [17] also found an increase in vertical dimensions after Bionator treatment, while Martina et al. [18], who examined the effects of the Sander "Bite Jumping" appliance and Freeman et al. [19], who analyzed the Fränkel functional regulator effects, concluded the unwanted clockwise rotation of the maxilla and mandible was both clinically and statistically insignificant. The important thing to consider here is the type of facial growth and vertical parameter values before treatment. Most patients from our sample were horizontal growers according to the Björk-Jaraback analyses, so the increase of the Björk polygon sum of angles led to neutral growth at the end of treatment.

Finally, incisor position parameters in this study's sample indicate upper incisor retrusion and lower incisor protrusion in all three groups at the end of treatment. Even though it was stiatistically significant, upper incisor retrusion was clinically insignificant in groups treated with the Fränkel functional regulator and Bionator, while it was clinically significant in the "M block" treated group. Lower incisor protrusion was clinically insignificant in all three groups at the end of treatment.

In Class II division 1 patients, overjet is typically increased due to upper incisor protrusion.[2] Upper incisor uprighting is commonly achieved during Andresen Activator [15], Balters' Bionator [12, 13, 22, 23], Herbst [4] and Fränkel [24] functional appliance treatment. Lower incisor protrusion is always present at the end of Andresen Activator [25], Balters' Bionator [12, 13] and Fränkel functional appliance [24] treatment. Freeman et al [19] found significant upper incisor retrusion and a less pronounces lower incisor protrusion at the end of Fränkel functional regulator treatment, while

Martina et al [18] concluded lower incisor protrusion was both clinically and statistically insignificant at the end of Sander's "Bite Jumping" appliance treatment.

CONCLUSION

Results of our study indicate efficiency in skeletal class II malocclusion treatment of all three types of functional appliances ("M block" appliance, Fränkel functional regulator type I and Balters' Bionator type I) investigated. Owing to significant mesial positioning and mandibular sagittal growth, sagittal maxillo-mandibular angle values decreased. Upper incisor retrusion and lower incisor protrusion additionally decreased the overjet. All three types of appliances produced neutral facial growth in patients at the end of treatment. Our results indicate all three types of functional appliances are suitable for skeletal class II malocclusion treatment of growing patients in everyday clinical practice.

NOTE

This paper is based on Dr Vladimir Ristic's PhD thesis.

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