Effects of Orthodontic Functional Appliances in Relation to Skeletal Maturation of Cervical Vertebrae in Class II Malocclusion

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Aim: *To evaluate the effects produced by functional orthodontic appliances at dental and skeletal level in relation to the level of skeletal maturation in class II patients.*

Study design: *Longitudinal and observational study.*

Patients selected for the study had been wearing Sander Bite Jumping Appliance (SBJA) for at least 12 months; they were first diagnosed (T1) with skeletal class II according to Ricketts' cephalometric analysis, and had had lateral cephalograms taken before and after orthopaedic treatment (T2). Variables studied at T1 and T2 were: facial convexity, inclination of the upper and lower incisors, and facial depth. Results were compared between T1 and T2 for each variable and in relation to cervical maturation stage (CVS) according to the Lamparski analysis. Statistical analysis was performed using Shapiro–Wilk, t-student, Analysis of Variance (ANOVA) and multiple comparison tests, taking as statistically significant a p-value <0.05.

Results: *A final sample of 235 patients was obtained. Statistically significant differences were found in the inclination of the mandibular incisors between T1 and T2 and among the different cervical stages when the functional appliances were placed in CVS1 ($p = 0.000$), CVS2 ($p = 0.04$) or CVS5 ($p = 0.048$). For the remaining variables, significant differences were also found between T1 and T2, but these differences were similar in all cervical stages.*

Conclusions: *A significant proclination of the mandibular incisors was found when the functional appliance was placed during CVS1, CVS2, or CVS5. Time of placement of the functional appliances was not statistically significant for the remaining variables studied.*

Keywords: *Functional appliances, skeletal maturation, skeletal class II, Sander Bite Jumping Appliance.*

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INTRODUCTION

Skeletal class II malocclusions occur in one-third of the general population who go to the dental clinic requesting orthodontic treatment [1,2]. A total of 80% of this malocclusion class is due to mandibular retrognathism, which can be managed using functional appliances at skeletal and dentoalveolar levels simultaneously[1,3,4].

It is essential to consider the most suitable treatment for the patient and the optimal moment for achieving the most successful outcome. Many patients who present a skeletal class II malocclusion require orthodontic treatment to address esthetic concerns. These patients present increased overjet together with an unfavorable facial profile, often leading to low self-esteem[5-8]. Correcting a class II malocclusion at the dental and skeletal levels through functional appliances has been shown to improve dental overjet and facial appearance in general, thus enhancing both the patient's self-esteem and social life[5,7]. Furthermore, an overjet of 4 mm or more makes these patients 3.1 times more likely to sustain dental trauma, which mainly affects the permanent upper central incisors[7,8].

Regarding the dental effects exerted by functional appliances, there seems to be a consensus in the literature that the maxillary incisors undergo retroinclination, while the mandibular incisors have a proclination[2,4,9]. However, at the skeletal level, there is still some debate regarding the use of these appliances. Some authors have shown that these functional appliances limit the development of the maxilla[2,9,10,] while others contend that they promote its physiological growth[11]. At the mandibular level, some authors [12,13] support functional appliances during the peak of growth to achieve more significant mandibular advancement, while others [10,14] argue that there is no difference in the degree of maturation when the appliances are placed.

Given the lack of consensus in the literature on this question, the purpose of the present study was to evaluate the effects of functional orthodontic appliances at the dental and skeletal levels in patients with class II malocclusion. according to the degree of skeletal maturation of the cervical vertebrae.

MATERIALS AND METHOD

Ethical considerations

This study was approved by the Ethics Committee for Drug Research (CEIm) (PIC-196-19) of Fundació Sant Joan de Déu, Barcelona, Spain, in October 2019. The study was conducted in accordance with the Helsinki Declaration and with the International Conference on the Guide to the Harmonization of Good Clinical Practice.

Study design and population

Accepting an alpha risk of 0.05 and a beta risk of 0.2 in a two-sided test, 32 participants were necessary to recognize as statistically significant a difference greater than or equal to 0.05 units. The standard deviation was assumed to be 0.05, and a drop-out rate of 0% was anticipated.

This was a descriptive, longitudinal, observational, and retrospective study. The database of the orthodontic and dentofacial orthopedic department of the Hospital HM Nens, HM Hospitales in Barcelona was consulted. A significant sample was obtained from patients visiting the orthodontic and dentofacial orthopedics department between 01 June 2017 and 31 December 2019. Confidentiality and anonymity were guaranteed at all times in both sample collection and publication of the results.

The inclusion criteria consisted of patients with skeletal class II malocclusion according to Ricketts' cephalometric analysis; who had used Sander Bite Jumping Appliance (SBJA) for at least 1 year (minimum 15 hours per day) as a dentofacial orthopedic treatment; and who had undergone a lateral cephalogram before and after treatment. Children with syndromes or developmental disorders were excluded from the study. Lateral cephalograms taken prior to (T1) and after (T2) the use of SBJA were compared. Facial convexity, inclination of both upper and lower incisors, and facial depth were all measured according to Ricketts' cephalometric analysis (Table 1)[15]. These variables were associated with the state of skeletal maturation according to Lamparski's analysis [cervical vertebrae stages 1 to 6 (CVS1–CVS6)] (Figure 1)[16].

Sander Bite Jumping Appliance (SBJA)

The patients were treated with SBJA (Figure 2), and the mandible was advanced in utmost protrusion of 6 mm with an opening of 4 mm. The appliance for the upper jaw was fitted out with a screw for the upper jaw and with protrusive elements long 16 mm (Figure 2). The length of these elements is a key part of the treatment, and for a good functioning of this appliance it is necessary to maintain their full length. The superior appliance screw allows to expand the maxillary arch when necessary. The appliance for the lower jaw showed an inclined plane. If the patient is biting these stainless-steel parts together, they are guided by the inclined plane [17,18].

Figure 1. Lamparski analysis.

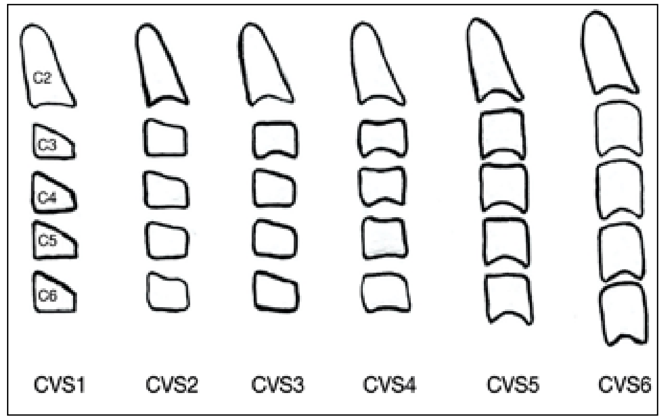
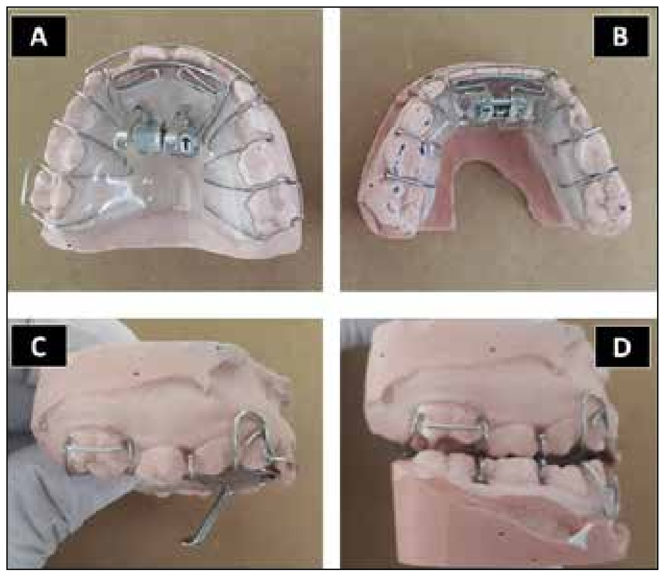


Figure 2. Sander bite jumping appliance; A, Maxillary plate; B, Mandibular plate; C, Lateral view of the elements long 16 mm; D, Lateral view showing how the two plates interconnect with each other determining a mandibular advancement



Cephalometric analysis

Cephalometric analysis was performed using Ortomed® EVO 2005 version (Infomed Servicios Informáticos S.L., Barcelona, Spain) with the corresponding updates. To avoid possible errors in measuring lateral cephalograms, the cephalometric study was performed by a single operator and calibrated by the prior performance of 100 cephalometries on patients who did not form part of the present sample. In analysing the medical records, the degree of patient collaboration (yes / no) regarding the use of functional appliances was also recorded. These records were compiled in a Microsoft Excel® table and analysed by a single operator.

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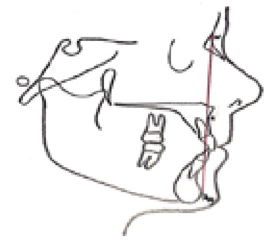
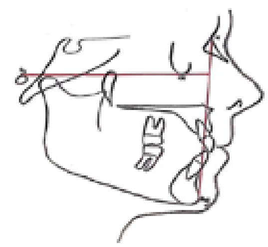
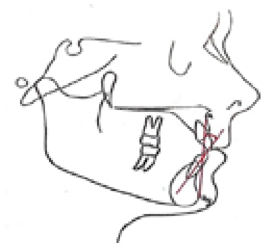
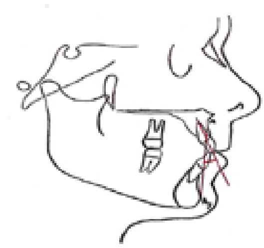
Table 1. Description of Ricketts' cephalometric landmarks analysed in this study

	Norm	Interpretation	Measurement	
Facial convexity	2 ± 2 mm at 9 years of age (decreases 0.2 mm annually)	A decrease in value suggests a class III skeletal pattern. An increase in value suggests a class II skeletal pattern.	Linear measurement between point A and the facial plane.	
Facial depth	87 ± 3° at 9 years of age (increases 0.3° annually until the cessation of facial growth)	A decrease in value suggests a retrusion in the chin position. An increase in value suggests an advancement of the chin position.	Angle between the horizontal Frankfurt plane and the facial plane.	
Maxillary incisor inclination	28 ± 4°	A decrease in value suggests an incisor retroinclination. An increase in value suggests an incisor proclination.	Angle between the longitudinal axis of the upper central incisor and the A-Pog line.	
Lower incisor inclination	22 ± 4°		Angle between the longitudinal axis of the lower central incisor and the A-Pog line.	

Statistical analysis

Means and standard deviations, together with percentages, were used to describe each of the variables. Normality of the variables was analysed using the Shapiro–Wilk contrast. As all the studied variables followed a normal distribution, the t-test contrast was used for paired data (to assess changes between T1 and T2), and Analysis of Variance (ANOVA) was used to assess whether there were statistically significant differences between T1 and T2, depending on the cervical stage. When statistically significant differences were observed between the groups, a multiple comparison test was performed to identify the stages at which these changes were significant. To determine whether there were differences according to the patient's gender, the two-factor ANOVA test was performed. A p value ≤ 0.05 was regarded as statistically significant. SPSS® Statistics version 25.0 (IBM, Armonk, NY, USA) was used for statistical analysis.

RESULTS

The initial sample consisted of 271 patients; following application of the inclusion and exclusion selection criteria, the final sample was 235 patients (115 females and 120 males). Thirty-six patients did not meet the inclusion criteria because 20 patients presented skeletal class I at T1 according to Ricketts' cephalometric analysis; 6 patients had no final lateral cephalogram; 2 patients wore functional appliances in combination with a multibracket system; the initial lateral cephalogram of 1 patient was not accessible; and 6 patient had been wearing SBJA for less than one year. The initial mean age of the participants was 9.8 ± 2.6 years. The patients were classified according to cervical stage: 75 in CVS1, 85 in CVS2, 30 in CVS3, 20 in CVS4, 10 in CVS5 and 15 in CVS6. The mean duration of treatment with expansion plates with SBJA was 28 ±13.43 months.

Patient cooperation

A total of 63.8% of the patients (n = 150) used SBJA for a minimum of 15 hours per day. The number of patients who cooperated in each cervical stage group was 50 in CVS1, 55 in CVS2, 25 in CVS3, 15 in CVS4, 5 in CVS5. No patients collaborated in CVS6.

Facial convexity

After wearing the functional appliances, a decrease in the patients' facial convexity was obtained at all cervical stages, with the exception of CVS6, where it increased. The decrease in facial convexity was statistically significant between T1 and T2 when the functional appliances were placed during CVS1 ($p = 0$), CVS2 ($p = 0.002$) or CVS4 ($p = 0.025$) (Table 2 and Figure 3). Despite this, differences between T1 and T2 among the six cervical stages were not statistically significant ($p = 0.226$); this means that no cervical stage presented significant changes when compared with the other stages. No statistically significant differences were found according to the patients' gender ($p = 0.552$).

Facial depth

An increase in facial depth was observed when SBJA were placed prior to or at the onset of the growth peak (CVS1, CVS2 and CVS3). In contrast, facial depth decreased when the appliances were placed in the later cervical stages (CVS4, CVS5 and CVS6). These differences were statistically significant between T1 and T2 when the functional appliances were placed during CVS1 ($p = 0.002$) or CVS2 ($p = 0.041$) (Table 2 and Figure 3). However, differences between T1 and T2 amongst the different maturation stages were not statistically significant ($p = 0.100$), because all the groups presented similar changes between T1 and T2. Regarding gender, a greater increase in the value of facial depth was found in females ($p = 0.045$)

Maxillary incisor inclination

When the functional appliances were placed at CVS1, CVS2, CVS4 or CVS5, maxillary incisor retroinclination was observed, while in the remaining groups (CVS3 and CVS6) the patients showed pro-inclination. At the beginning of the treatment with functional appliances in CVS2, maxillary incisor inclination underwent a statistically significant change between T1 and T2 ($p = 0.04$) (Table 3 and Figure 3). However, the change in incisor inclination was similar across the six cervical stages, showing no statistically significant differences ($p = 0.582$). There were no statistically significant differences according to gender in relation to any final maxillary incisor inclination ($p = 0.165$).

Lower incisor inclination

Proclination was observed in all the study groups and was statistically significant when functional appliances were placed at CVS1 ($p = 0$), CVS2 ($p = 0.004$), or CVS5 ($p = 0.048$) (Table 3 and Figure 3). In this case, differences in the final inclination were statistically significant across the stages ($p = 0.045$); in other words, a greater incisor inclination was obtained when placing the functional appliances at CVS1, followed by CVS5 and CVS2. Regarding gender, no statistically significant differences were found ($p = 0.445$).

Figure 3. Comparison of the absolute value of the change in the variables (T2–T1) depending on the cervical stage. 4A: facial convexity (mm), 4B: facial depth (°), 4C: maxillary incisor inclination (°), 4D: lower incisor inclination (°).

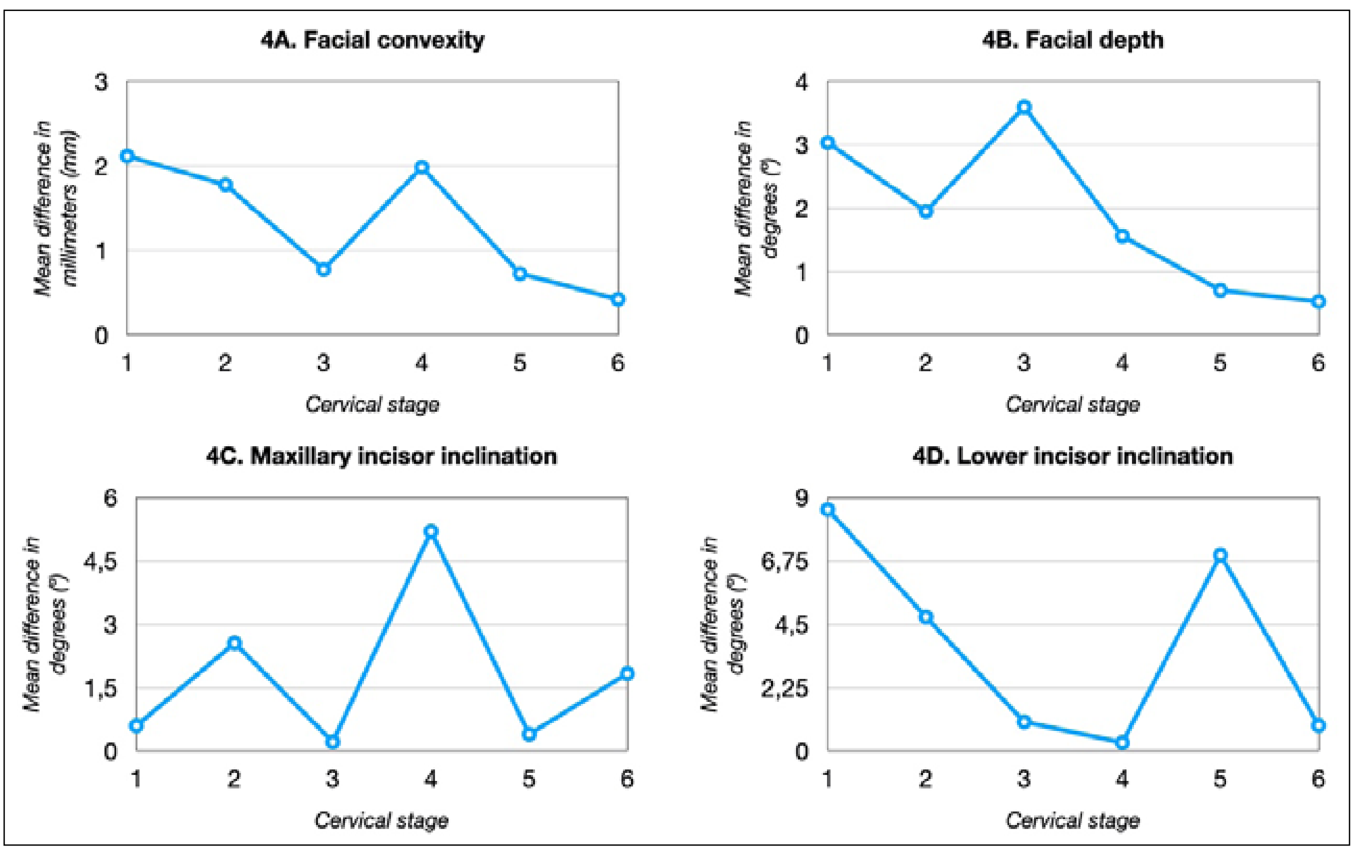


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Table 2. Comparison between T1 and T2 of facial convexity (mm) and facial depth (º) (*p ≤ 0.05)

Cervical stage		Facial convexity (T1)	Facial convexity (T2)	Difference	Facial depth (T1)	Facial depth (T2)	Difference
1	N	75	75	75	75	75	75
	Mean	6.0047	3.8847	–2.118	83.094	86.1273	3.0333
	Standard deviation	1.37667	1.79975	1.53857	3.50153	4.15262	3.04633
	p value		**0.000***			**0.002***	
2	N	85	85	85	85	85	85
	Mean	5.8165	4.0382	–1.7782	84.2347	86.1859	1.9512
	Standard deviation	1.30675	2.22679	2.00345	3.84625	2.60672	3.62623
	p value		**0.002***			**0.041***	
3	N	30	30	30	30	30	30
	Mean	6.005	5.23	–0.775	85.2533	88.85	3.5967
	Standard deviation	1.99218	2.63278	1.55611	4.13575	3.24984	4.14909
	p value		**0.277**			**0.087**	
4	N	20	20	20	20	20	20
	Mean	5.5575	3.5725	–1.985	87.295	85.735	–1.56
	Standard deviation	1.7895	0.86446	0.95445	4.05609	3.19973	3.76384
	p value		**0.025***			**0.468**	
5	N	10	10	10	10	10	10
	Mean	4.65	3.925	–0.725	87.335	86.63	–0.705
	Standard deviation	1.06066	1.19501	0.13435	2.21324	4.00222	1.78898
	p value		**0.083**			**0.676**	
6	N	15	15	15	15	15	15
	Mean	5.7333	6.1567	0.4233	83.4333	82.9067	–0.5267
	Standard deviation	2.49143	2.80447	2.99524	2.17417	0.92662	1.28204
	p value		**0.829**			**0.551**	

DISCUSSION

In line with previous studies[10,14], the present results indicate that SBJA is effective in correcting skeletal class II malocclusions as a result of the combination of skeletal and dentoalveolar effects they exert.

Facial convexity and facial depth were evaluated at the skeletal level after patients had worn the functional mandibular appliances. Despite the fact that these appliances have a minimal effect on the upper jaw[19], different studies [2,6,9,10,20] show a restriction of maxillary growth when orthodontic appliances such as Twin-block, Herbst or SBJA are worn. However, Gazzani *et al*[11], who also studied the effect exerted by SBJA, observed an advancement of point A at all the cervical stages analysed (CVS1–CVS4). The forward and downward movement of point A was also observed in other studies [2,11] when other functional devices such as the mandibular anterior repositioning appliance (MARA) or Bionator were used, suggesting that these devices did not restrict maxillary growth. It is important to note that anterior movement of the apices of the upper incisors can lead to bone remodelling and advancement of point A[1,10].

A decrease in facial convexity and correction of skeletal class II malocclusion were observed in the present study after the use of the functional appliances at all cervical stages, with the exception of CVS6, where they increased. The decrease in facial convexity was found to be due to a more posterior position of point A with respect to the facial plane.

Zelderloo e*t al* [9] observed that the greater the cervical stage was at the time of placement of the orthopedic appliance, the fewer skeletal changes were obtained. These results are in agreement with those obtained in our study, in which an increased facial depth was achieved when the functional appliances were placed before or at the onset of the growth peak (CVS1–CVS3). However, when the orthopedic treatment was started at later stages (CVS4–CVS6), a chin retrusion developed. By contrast, Ardeshna *et al* [2] observed mandibular advancement in all age groups, and thus increased facial depth. Although the mandibular advancement that they obtained was not statistically significant when compared with the control group, this advancement may have been due to the fact that, in their study, Ardeshna *et al* [2] used a fixed functional appliance (MARA). It

Table 3. Comparison between T1 and T2 of maxillary and lower incisor inclination (º) (*p ≤ 0.05)

Cervical stage		Maxillary incisor inclination (T1)	Maxillary incisor inclination (T2)	Difference	Lower incisor inclination (T1)	Lower incisor inclination (T2)	Difference
1	N	75	75	75	75	75	75
	Mean	33.9833	33.3847	–0.5987	18.0927	26.8653	8.5727
	Standard deviation	7.32758	4.98644	6.89875	6.53793	4.68094	4.93232
	p value		**0.742**			**0.000***	
2	N	85	85	85	85	85	85
	Mean	33.2729	30.7182	–2.5547	21,3276	26.0871	4.7594
	Standard deviation	7.62423	5.35486	4.70511	6.90954	5.65571	5.7534
	p value		**0.04***			**0.004***	
3	N	30	30	30	30	30	30
	Mean	34.44	34.6567	0.2167	19.1717	20.2067	1.035
	Standard deviation	7.69182	4.28258	7.54999	6.07437	4.65758	8.16561
	p value		**0.947**			**0.769**	
4	N	20	20	20	20	20	20
	Mean	30.0275	24.8325	–5.195	24.1425	24.445	0.3025
	Standard deviation	15.39666	8.75478	6.85225	5.51094	5.81579	6.11165
	p value		**0.227**			**0.927**	
5	N	10	10	10	10	10	10
	Mean	27.675	27.28	–0.395	15.99	22.945	6.955
	Standard deviation	6.71044	2.81428	3.89616	6.36396	7.10642	0.74246
	p value		**0.909**			**0.048***	
6	N	15	15	15	15	15	15
	Mean	34.25	36.0833	1.8333	20.0167	20.9233	0.9067
	Standard deviation	10.18996	9.41656	3.94645	8.3981	9.27707	6.85124
	p value		**0.505**			**0.84**	

is important to note that removable mandibular advancement functional appliances were used in both the present study and by Zelderloo *et al* [9] Vaid *et al*[19] concluded that a greater mandibular length is achieved by using fixed functional appliances (2.29 mm more than in the untreated group) compared with removable orthodontic functional appliances (1.61 mm more than in the control group).

Following the use of functional appliances, Kinzinger *et al* [4] observed mandibular incisor proclination and maxillary incisor retroinclination, thus producing a decrease in overjet. Not only do the results of that study accord with other findings,[5,9,10,14] they have also recently been validated by other authors as well[2,11,21]. Most of the results obtained in the present study corroborate those previously mentioned. However, maxillary incisor proclination was shown when the functional appliances were placed during CVS3 and CVS6. These differences can be explained by the small sample size of the CVS6 group, and also by the lack of collaboration of fifteen patients in this group. On the other hand, ten of the thirty patients who wore functional appliances during CVS3 also did not collaborate with the treatment. Therefore, these results should be interpreted with caution.

Regarding the optimal timing for the placement of functional appliances, Pavoni *et al* [12] observed that, upon completion of treatment with functional appliances before puberty, the long-term effects were mainly limited to the dentoalveolar level, despite the fact that, immediately after removal, significant skeletal changes were observed. In addition, when treatment with functional appliances included the growth peak, skeletal level changes were greater and more stable in the long term. Baysal and Uysal [5] and Siara-Olds *et al* [20] also observed that the greatest changes were obtained when the growth peak was included in the treatment with functional appliances. Kinzinger et al[4] observed that during the post-pubertal stage, changes were produced at both dental and skeletal levels, with the dentoalveolar ones being the most predominant (70% of the final effect). The same results were obtained by Jouybari *et al* [6], who observed that, even 6 months after menarche, good results were found when placing the functional appliances, although the effects were greater at dental level.

In contrast, other authors[9,14] did not find significant differences when placing functional appliances at one cervical stage or another. These results coincide with those obtained in the present study, in which only statistically significant differences related to cervical maturation were found when evaluating the inclination of the lower incisors. However, it is important to note that, despite there being no statistically significant differences between cervical stages, better results were obtained at the skeletal level by placing functional appliances during the early stages of cervical development (CVS1–CVS3).

In terms of gender, O'Brien *et al* [22] obtained a higher correction of class II malocclusions in females, while more recent studies[5,9,14] concluded that these gender-based differences are non-existent at the dental or skeletal level. Although the present study found statistically significant differences when analysing facial depth, these results should be interpreted with some caution, because the p value obtained was very close to the established limit; this finding cannot be taken to be confirmed.

Among the limitations of this study are not only the retrospective nature of the research but also the lack of evaluation of the stability of long-term changes following the use of the fixed multibracket appliance, or even later. Furthermore, despite obtaining a final sample larger than that deemed necessary to obtain statistically significant results, the groups were very heterogeneous. Consequently, the number of participants in four of the groups (CVS3, CVS4, CVS5 and CVS6) was limited, which may have compromised the reliability of the results obtained. The use of a small sample at the stages indicated means that the statistical contrast is insufficient to detect statistically significant differences. For this reason, the results achieved in these groups should be interpreted with caution and confirmed by a larger sample and with more homogeneous groups. Moreover, the lack of collaboration of 36.2% of the patients means that some groups had no patient collaboration at all.

CONCLUSIONS

1. Use of SBJA as mandibular advancement appliances in patients presenting Class II malocclusion produces beneficial changes in each of the variables assessed: facial convexity, facial depth, and maxillary and mandibular incisor inclination.
2. The patients' cervical stage at the time of placement of the appliances was not significant for most of the variables evaluated; however, the pro-inclination of the mandibular incisors was significantly higher when functional appliances were placed during CVS1, CVS5, or CVS2.
3. The results of the present study seem to show that better results are obtained both at dental and skeletal levels when functional appliances are placed before or at the beginning of the peak of growth (CVS1–CVS3).

Conflict of interest

The authors declare no conflict of interest.

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