Original Article

Effectiveness of removable anterior bite planes with varied mealtime protocols in correcting deep bites among growing patients: a randomized clinical trial

Thanapat Sangwattanarat[a]; Udom Thongudomporn[b]

ABSTRACT

Objectives: To compare effectiveness of two protocols for correcting deep bite in growing patients using a removable anterior bite plane (RABP): full-time wear with appliance on during meals (F + M) vs off during meals (F − M) and to explore the relationship between average daily duration of wear and overbite (OB) correction rate, stratified by the wear protocol.

Materials and Methods: Thirty-two growing patients with deep bite (mean age = 10.94 ± 2.17 years) were randomly assigned to the F + M (n = 16) or F − M (n = 16) group. Cephalometric radiographs were taken at baseline (T0) and when normal OB was achieved (T1). Duration of wear was recorded by a TheraMon microsensor within the appliance. A best-fit regression model for the relationship between daily duration of wear and OB correction rate was determined ($\alpha = 0.05$).

Results: Both groups exhibited similar baseline characteristics and cephalometric changes, ie, molar extrusion, and incisor intrusion and proclination in both arches ($P < .05$), and intergroup differences were not significant. Here, F + M exhibited significantly faster rates of deep bite correction (1.83 ± 1.18 vs 1.08 ± 0.62 mm/month; $P < .05$) and mandibular molar extrusion (0.46 ± 0.25 vs 0.30 ± 0.18 mm/month, $P < .05$) compared with F − M. Best-fit regression models for relationship between daily duration of wear and OB correction rate were exponential for both F + M ($R^2 = 0.53$) and F − M ($R^2 = 0.74$).

Conclusions: Here, F + M and F − M protocols resulted in comparable cephalometric changes among deep bite growing patients. However, the F + M group exhibited a faster correction rate. Daily duration of wear positively correlated with OB correction rate in an exponential manner. (*Angle Orthod*. 2024;94:615–622.)

KEY WORDS: Anterior bite plane; Deep bite; Rate of overbite change; Treatment duration; Wear duration

INTRODUCTION

Deep bite, characterized by excessive vertical overlap of the maxillary and mandibular incisors of >40% of the mandibular incisor clinical crown,[1] necessitate early treatment during growth to capitalize on masticatory muscle adaptation.[2,3] A removable anterior bite plane (RABP) is commonly employed for this purpose, facilitating mandibular posterior tooth extrusion and, to a lesser extent, mandibular incisor proclination.[4,5]

Generally, an RABP should be worn full time, except during brushing. However, a variety of RABP protocols have been suggested. Some advocate continuous wear during meals to allow constant disocclusion of the posterior teeth, preventing posterior teeth from being exposed to chewing forces, thus expediting extrusion of the posterior teeth.[6,7] Others suggest mealtime removal.[8,9] It is arguable that, although the chewing force is heavy, the cumulative duration of chewing per day is insufficient to affect orthodontic tooth movement. Despite theoretical differences, the impact on treatment effectiveness remains uncertain.

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There were two purposes of this study. The first was to compare deep bite correction rate following the full-time use of an RABP in a group of growing patients with deep bite following two different protocols: the appliance on during meals (F + M group) and appliance off during meals (F − M group). The second purpose was to explore the relationship between average daily duration of wear and overbite (OB) correction rate, stratified by protocol.

MATERIALS AND METHODS

Trial Design

This two-arm parallel study was a single-center, randomized control trial with a 1:1 allocation ratio and followed an intention-to-treat protocol. The trial was approved by the Human Research Ethics Committee (HREC) of the Faculty of Dentistry, Prince of Songkla University (Ethical Approval Number: EC6601-001) and was registered at the Thai Clinical Trial Registry (TCTR20230305001).

Sample Size Calculation

The sample size was calculated based on a previous study[4] of dental changes in growing patients with deep OB during treatment with an RABP. Calculations using G*Power software (version 3.1, Heinrich Heine University Düsseldorf, Düsseldorf, Germany) based on the mean difference of the change in OB (1.4 and 3.1 mm) and standard deviation (1.5 and 1.3) between groups, an effect size of 1.21, $\alpha = 0.05$, and $\beta = 0.90$ determined that the required sample size was 16 subjects per group.

Participants, Eligibility Criteria, and Setting

Subjects were recruited consecutively at the Orthodontic Clinic of the Dental Hospital, Faculty of Dentistry, Prince of Songkla University, Thailand. The inclusion criteria were (i) dental deep bite (OB > 40%), (ii) Angle Class I or II molar relationship, (iii) skeletal Class I or mild Class II (ANB = 1–9°), (iv) growing patient (CVM stage ≤ CS5), (v) normodivergent or hypodivergent pattern (SN-MP < 35°), (vi) no signs and symptoms of temporomandibular disorders, and (vii) no history of orthodontic treatment. The exclusion criteria were (i) noncooperative patients, (ii) incomplete root formation of the mandibular incisors on panoramic radiography, (iii) clinical absence of maxillary or mandibular first molars or incisors, or (iv) long-term use of anti-inflammatory or immunosuppressive medications.

Randomization and Blinding

Before subject recruitment, computer-generated numbers were assigned to allocate all subjects to either the F + M or F − M group (n = 16 per group). The numbers were printed, sealed in envelopes, and randomly selected by participants, ensuring single-envelope selection and sequence adherence. All subjects and their parents provided written informed consent before participating. Treatment was administered by a single orthodontist, with data collection and measurements conducted by one researcher. While subjects and the orthodontist were aware of the wear protocol, the researcher remained blinded to subject identification and allocation during statistical analysis.

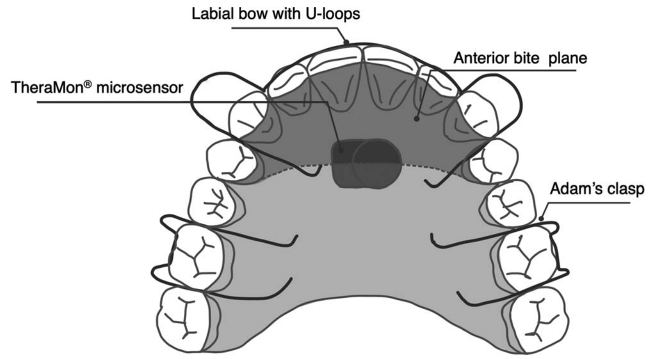


Figure 1. Components of the removable anterior bite plane (RABP) and the position of the embedded temperature microsensor (TheraMon).

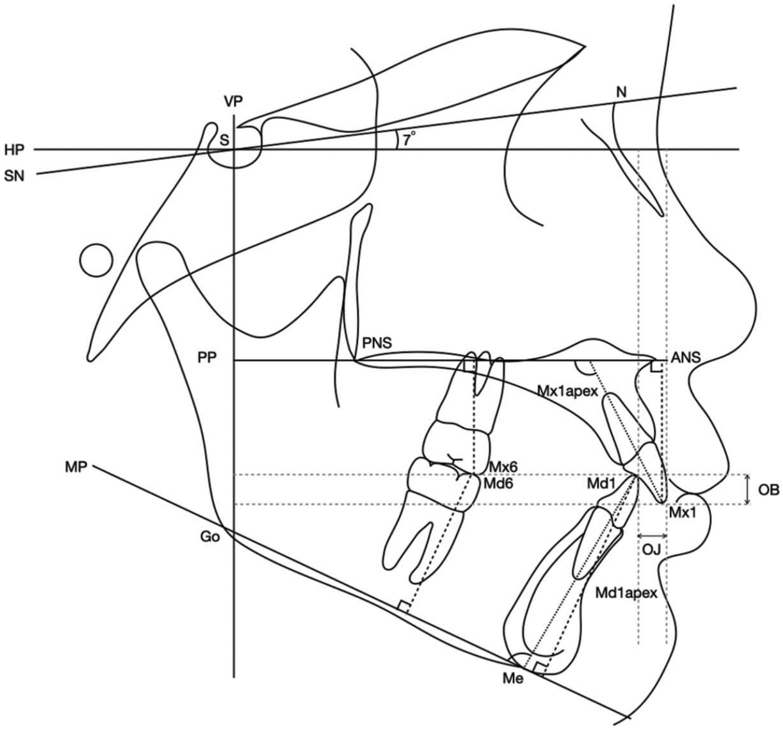
Appliance Design and Intervention

The RABP comprised Adam's clasps at the maxillary first molars, a labial bow, and a polymethyl methacrylate (PMMA) baseplate with an anterior bite plane. The upper and lower dental models were articulated in centric relation position with a predetermined 2-mm gap between the first permanent molars. Mandibular incisors consistently occluded on the bite plane. A temperature microsensor (TheraMon, Hargelsberg, Austria) was embedded in the baseplate close to the palatal soft tissue during wear (Figure 1).

Subjects in the F + M group were instructed to wear the appliances full time, except during tooth brushing, while subjects in the F − M group were instructed to wear the appliances full time, except during meals and tooth brushing. All subjects were recalled monthly until normal OB was achieved (2 mm of clinical OB measured by a single orthodontist using a 1-mm-scale periodontal probe).

Cephalometric Evaluation

Lateral cephalograms were taken before treatment (T0) and after achieving normal OB (T1) in natural head position using the same radiographic machine. Cephalometric data were analyzed with Dolphin Imaging software (version 11.9, Dolphin Imaging, Chatsworth, CA, USA). Cephalograms were measured and



Landmarks	Definitions
Skeletal divergence (SN-MP)	The angle formed between the SN plane and mandibular plane (MP).
Overbite (OB)	The distance between the maxillary and mandibular incisal edge (Mx1-Md1) parallel to the vertical reference plane (VP).
Maxillary incisor vertical position (Mx1-prepPP)	The distance between the maxillary incisal edge (Mx1) perpendicular to the palatal plane (PP).
Inclination of the maxillary incisor (Mx1-PP inclination)	The angle between the long axis of the maxillary incisor (Mx1-Mx1apex) and palatal plane (PP).
Mandibular incisor vertical position (Md1-prepMP)	The distance between the mandibular incisal edge (Md1) perpendicular to the mandibular plane (Go-Me).
Inclination of the mandibular incisor (Md1-MP inclination)	The angle formed between the long axis of the mandibular incisor (Md1-Md1apex) and the mandibular plane (MP).
Maxillary molar vertical position (Mx6-prepPP)	The distance between the mesiobuccal cusp of the maxillary molar (Mx6) perpendicular to the palatal plane (PP).
Mandibular molar vertical position (Md6-prepMP)	The distance between the mesiobuccal cusp of the mandibular molar (Md6) perpendicular to the mandibular plane (MP).

Figure 2. Linear and angular cephalometric measurements used in this study.

analyzed by one single-blinded researcher. Cephalometric measurements included skeletal divergence (SN-MP), OB, maxillary incisor vertical position (Mx1-perpPP), inclination of maxillary incisor (Mx1-PP inclination), mandibular incisor vertical position (Md1-perpMP), inclination of mandibular incisor (Md1-MP inclination), maxillary molar vertical position (Mx6-perpPP), and mandibular molar vertical position (Md6-perpMP) (Figure 2).

Measurement of the Duration of Wear

The microsensor embedded within the RABP recorded the duration of wear, with data collected by a pen reader via radiofrequency identification (RFID) and transferred to a computer. TheraMon software was used to calculate the duration of wear and the average daily duration of wear. The software was set to detect a wearing temperature range of 32–40°C, indicative of intraoral RABP wear. To ensure accurate measurement, participants were informed to avoid consuming cold drinks or foods and not to clean or soak the RABP in warm or hot water.

Rates of Change of Cephalometric Parameters

The following formula was used to calculate the rate of change for each cephalometric parameter (amount/month):

$$\frac{\text{Cephalometric value at T1} - \text{Cephalometric value at T0}}{\text{Total treatment duration (month)}}.$$

Method Error Analysis

Ten randomly selected cephalograms were remeasured by the same researcher after 4 weeks. Dahlberg's error analysis showed <0.3 mm for linear variables and 0.5° for angular variables. The intraclass correlation coefficient ranged from 0.96 to 0.99, indicating acceptable accuracy and reliability for all measurements.

Statistical Analysis

Statistical analysis was performed using SPSS version 29 (SPSS Inc., IBM, Armonk, NY, USA). The Shapiro-Wilk test indicated there was a nonnormal distribution for some outcomes. Therefore, nonparametric analyses were performed when appropriate. Sex distribution was assessed using Pearson χ^2. Baseline characteristics were compared between groups using a Mann-Whitney *U*-test. Cephalometric changes within each group between timepoints were analyzed using the Wilcoxon signed-rank test or paired sample *t*-test. Differences between groups were analyzed with a Mann-Whitney *U*-test or independent *t*-test. Thereafter, various regression models were analyzed to find the best-fit model for the relationship between the duration of wear and OB correction rate based on R^2 values. The significance level was set at 0.05.

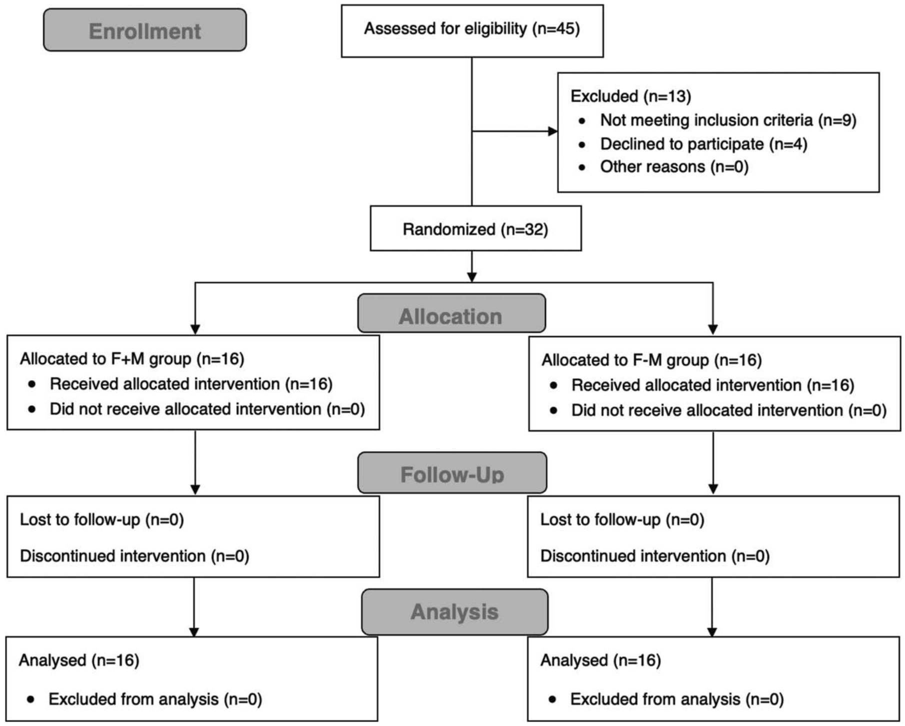


Figure 3. CONSORT flow diagram for this study.

RESULTS

Forty-five patients initially enrolled in the study. Nine were excluded because they did not meet the inclusion criteria, and four declined participation. The remaining 32 subjects (14 males and 18 females; mean age $\pm$ SD $=$ 10.94 $\pm$ 2.17 years) were randomly allocated into the F $+$ M or F $-$ M group. No dropouts occurred during the study (Figure 3). There were no statistically significant differences between the groups in terms of sex, age, and skeletal and dental parameters (Table 1).

Table 1. Comparison of baseline (T0) characteristics and cephalometric measurements between groups[a]

	F + M (n = 16)		F − M (n = 16)		
Variables	Mean	SD	Mean	SD	*P* Value
n (male : female)	8:8		6:10		.688[b]
Age (y)	11.00	2.09	10.87	2.33	.877[c]
SN-MP (°)	31.97	2.80	32.71	2.33	.439[c]
Overbite (mm)	5.94	2.16	5.44	1.19	.509[c]
Mx1-perpPP (mm)	25.24	2.58	25.34	1.93	.901[d]
Mx1-PP inclination (°)	114.16	8.71	116.70	7.61	.389[d]
Md1-perpMP (mm)	36.38	3.38	37.19	2.16	.433[d]
Md1-MP inclination (°)	93.83	6.17	93.96	5.21	.948[d]
Mx6-perpPP (mm)	18.69	2.02	18.99	1.58	.644[d]
Md6-perpMP (mm)	26.66	2.59	27.14	2.02	.561[d]

[a] F + M, full-time appliance wearing except for tooth brushing; F − M, full-time appliance wearing except for meals and tooth brushing.
[b] Pearson χ^2 test.
[c] Mann-Whitney *U*-test.
[d] Independent sample *t*-test.

No harmful events or side effects, namely, gingival inflammation or recession, severe tooth mobility, or dental pain, occurred among the participants.

Within-groups analysis revealed similar, significant cephalometric changes in both the F $+$ M and F $-$ M groups, including decreases in OB, Mx1-perpPP, and Md1-perpMP, along with increases in Mx1-PP and Md1-MP inclination, Mx6-perpPP, and Md6-perpMP (all $P < .001$, except Md1-prepMP in F-M group, $P < .01$; Table 2).

Between-groups comparisons indicated no significant differences in cephalometric parameter changes and rates of changes ($P > .05$; Tables 3 and 4), except for a higher rate of OB change in the F $+$ M group (-1.83 ± 1.18 mm/month) than the F $-$ M group (-1.08 ± 0.62 mm/month; $P < .05$) and a higher rate of Md6-perpMP change in the F $+$ M group (0.46 ± 0.25 mm/month) than the F $-$ M group (0.30 ± 0.18 mm/month; $P < .05$). The average daily duration of wear was significantly longer in the F $+$ M group (22.69 ± 1.10 hours) than in the F $-$ M group (19.41 ± 2.33 hours; $P < .001$; Table 4).

In analyzing the relationship between the daily duration of wear and the OB change rate, linear regression models yielded R^2 values of 0.42 for the F $+$ M group and 0.60 for the F $-$ M group, whereas exponential regression models yielded R^2 of 0.53 and 0.74 for the F $+$ M and F $-$ M groups, respectively. The best-fit regression model for the F $+$ M group was

Table 2. Comparison of the changes in cephalometric measurements within each group between T0 and T1[a]

	F + M (n = 16)					F − M (n = 16)				
	T0		T1			T0		T1		
Variables	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
Overbite (mm)	5.94	2.16	1.83	0.74	< .001[b***]	5.44	1.19	1.68	0.70	< .001[c***]
Mx1-perpPP (mm)	25.24	2.58	24.42	2.36	< .001[b***]	25.34	1.93	24.69	1.84	< .001[c***]
Mx1-PP inclination (°)	114.16	8.71	117.35	8.25	< .001[c***]	116.70	7.61	119.54	7.36	< .001[c***]
Md1-perpMP (mm)	36.38	3.38	35.81	3.32	< .001[c***]	37.19	2.16	36.80	2.02	.004[c**]
Md1-MP inclination (°)	93.83	6.17	96.60	6.50	< .001[c***]	93.96	5.21	96.62	5.02	< .001[c***]
Mx6-perpPP (mm)	18.69	2.02	19.45	2.17	< .001[c***]	18.99	1.58	19.63	1.43	< .001[c***]
Md6-perpMP (mm)	26.66	2.59	27.89	3.12	< .001[c***]	27.14	2.02	28.36	1.90	< .001[c***]

[a] F + M, full-time appliance wearing except for tooth brushing; F − M, full-time appliance wearing except for meals and tooth brushing.
[b] Wilcoxon signed rank test.
[c] Paired sample *t*-test.
* $P < .05$, ** $P < .01$, *** $P < .001$.

$y = 0.00001822 \times (0.498)^x$ and for the F − M group was $y = 0.016 \times (0.211)^x$, where y represents the rate of OB change and x represents the daily duration of wear (Figure 4).

DISCUSSION

The effectiveness of F + M and F − M protocols in growing patients with deep bite treated using an RABP may be compared in two aspects: outcome achieved and rate of achievement. Both protocols alleviated deep bite by inducing molar extrusion, proclination, and intrusion of the incisors. However, the F + M group exhibited a faster rate of deep bite correction and mandibular molar extrusion than the F − M group. The deep bite correction rate was positively and exponentially related to daily duration of wear, regardless of the wear protocol.

Full-time posterior disocclusion, including during mastication in the F + M group, may alter the functional posterior occlusal contact pattern and disrupt the equilibrium between bite forces and eruptive forces within the periodontal tissues, potentially resulting in a higher mandibular molar extrusion rate.[10,11] However, the reported effects of a compulsory increase in the vertical dimension on maximum bite force were inconsistent.[12,13] Authors of a recent study involving children with deep OB treated with an RABP found that posterior maximum bite force remained unchanged throughout the 6 months of appliance use compared with the bite force before appliance insertion.[14] It remains inconclusive whether the administration of an RABP with different protocols would affect posterior bite force differently. A controlled study comparing magnitude, direction, and distribution of posterior bite force in F + M and F − M groups could shed light on the influence of wear protocol on bite force.

Dentoalveolar growth and treatment may have contributed to the significant mandibular molar extrusion, as authors of a study reported the mandibular molar eruption rate of untreated children with deep bite to be approximately 0.10 mm/month.[15] On the other hand, maxillary molar extrusion in the present study may have been due solely to dentoalveolar growth. This was supported by authors of a previous study that reported a nonsignificant difference in maxillary molar vertical position between controls and subjects treated with an RABP.[15]

The OB change rate of 1.08–1.83 mm/month in the present study was faster than the rate of 0.53–0.57 mm/month reported by authors of previous studies using a similar appliance design in children of a similar age with deep bite[5,15]; however, the mandibular molar extrusion rates were comparable between studies. Proclination of the mandibular incisors in the present study may have contributed to the faster OB change rate since proclination causes relative intrusion. Determining the amount of true intrusion by measuring vertical displacement of the centroid of the incisors may

Table 3. Comparison of cephalometric changes (T1-T0) between groups[a]

	F + M (n = 16)		F − M (n = 16)		
Variables	Mean	SD	Mean	SD	*P* Value
Overbite (mm)	−4.11	2.10	−3.76	0.79	.777[b]
Mx1-perpPP (mm)	−0.82	0.55	−0.66	0.58	.345[b]
Mx1-PP inclination (°)	3.19	2.40	2.83	1.94	.692[b]
Md1-perpMP (mm)	−0.57	0.58	−0.39	0.44	.299[b]
Md1-MP inclination (°)	2.77	1.66	2.66	1.67	.855[c]
Mx6-perpPP (mm)	0.76	0.72	0.64	0.33	.985[b]
Md6-perpMP (mm)	1.24	1.07	1.21	0.69	.763[b]

[a] F + M, full-time appliance wearing except for tooth brushing; F − M, full-time appliance wearing except for meals and tooth brushing. Negative values indicate a decrease; positive values signify an increase.
[b] Mann-Whitney *U*-test.
[c] Independent sample *t*-test.

Table 4. Treatment duration, average duration of wear per day, and rates of change in cephalometric parameters in the F + M and F − M groups[a]

Variables	F + M (n = 16) Mean	SD	F − M (n = 16) Mean	SD	*P* Value
Treatment duration (months)	2.79	1.91	4.46	2.17	.015*
Average duration of wear (hours/day)	22.69	1.10	19.41	2.33	<.001***
Overbite change rate (mm/month)	−1.83	1.18	−1.08	0.62	.013*
Mx1-perpPP rate (mm/month)	−0.39	0.39	−0.19	0.20	.073
Mx1-PP inclination rate (°/month)	1.32	0.89	0.79	0.68	.052
Md1-perpMP rate (mm/month)	−0.29	0.37	−0.11	0.12	.056
Md1-MP inclination rate (°/month)	1.17	0.66	0.76	0.70	.067
Mx6-perpPP rate (mm/month)	0.29	0.24	0.19	0.15	.213
Md6-perpMP rate (mm/month)	0.46	0.25	0.30	0.18	.038*

[a] F + M, full-time appliance wearing except for tooth brushing; F − M, full-time appliance wearing except for meals and tooth brushing. Negative values indicate a decrease; positive values signify an increase.
* $P < .05$, ** $P < .01$, *** $P < .001$; Mann-Whitney *U*-test.

provide more detailed insight into the effect of the RABP on lower incisor movement.[16]

The observation of incisor proclination in the present study contrasted with previous studies[5,17] in which authors reported only molar extrusion without incisor inclination changes after the use of an anterior bite plane. Variations in the appliance design and sample characteristics, including skeletal pattern and initial mandibular incisor inclination, may have contributed to the differences between studies. In a recent study,[5] although the appliance was similar to the RABP used in this study, the subjects tended to be more hypodivergent than the subjects in the present study. Greater mandibular anterior rotation in hypodivergent patients may cause the anterior bite force to pass closer to the mandibular incisor long axis and lead to insignificant changes in dental inclination. In another study, a bite plane with an inclined plane was designed,[17] which may have allowed the anterior bite force to pass through the lower incisor long axis. However, caution should be exercised when using an inclined plane, as it may unintentionally force the mandible into a forward or backward position.

The TheraMon microsensor enabled accurate recording of the duration of wear compared with traditional data collection methods such as patient self-reported logbooks.[18] Subjects in the F + M group were expected to have an average daily duration of wear as close to 24 h/d as possible. The subjects in the F − M group were expected to wear the appliance for an average of 21 h/d, assuming that approximately 3 h/d for meals was allowed. The average daily durations of wear of 22.69 hours for the F + M group and 19.41 hours for the F − M group reflected about 92–94% adherence to the wear instructions. These results may have been affected by the Hawthorne effect because subjects were aware they were being closely observed; thus, the level of compliance may be outside of experimental conditions. Further research is needed

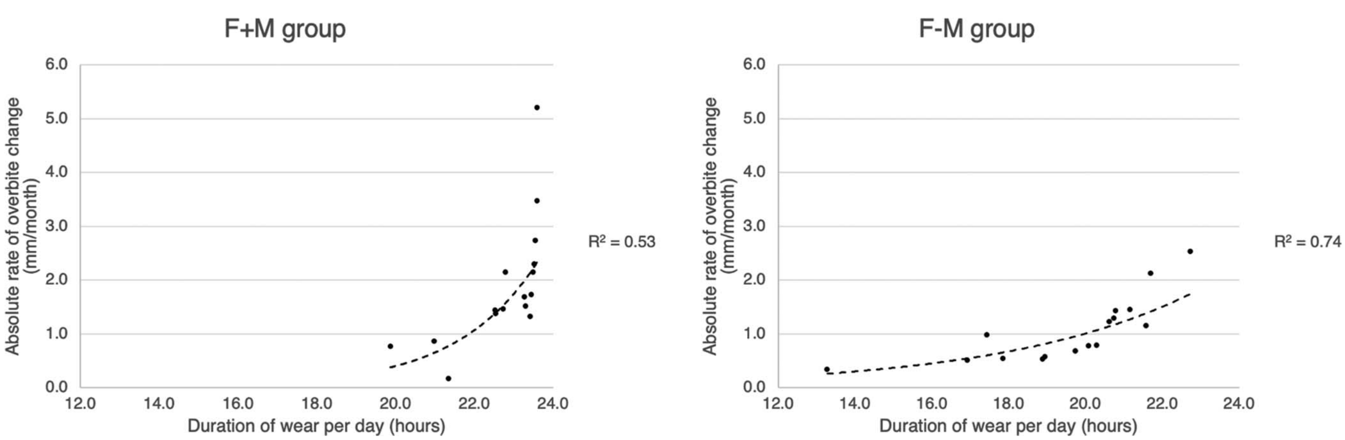


Figure 4. Regression modeling of the rate of overbite change (mm/month) as a function of the duration of wear per day (hours) in the F + M (left) and F − M (right) groups.

to investigate the level of compliance with each of these wear protocols.

The positive, exponential regression model depicting the relationship between average daily duration of wear and the rate of OB change, regardless of the wear protocol, suggested that wearing the appliance for a longer duration per day would lead to a faster reduction in OB, following an exponential trend. However, the regression models had R^2 values of 0.53–0.74, indicating that only 53–74% of the variance in the OB change rate was accounted for by the daily duration of wear. The remaining 26–47% of the variability in the OB change rate cannot be explained by the model and may be attributed to other factors not included in the analysis. Individual variations in bite force and the area of occlusal contact during chewing are among the potential contributing factors that could have affected the deep bite correction rate.

This study included children in both prepubertal and pubertal growth stages. Authors of a previous report indicated more favorable deep bite correction outcomes during pubertal growth.[4] Further studies in which authors stratify subjects according to their growth status are recommended. Investigating the link between occlusal contact pattern changes and cephalometric changes may help us understand the mechanism of deep bite correction with an RABP. This study lacked a negative control group to assess cephalometric changes in untreated individuals, which could provide valuable insight into the natural progression of the condition. Additionally, further investigation into the potential side effects of RABP use on root length changes is warranted. It is also important to note that the generalization of study results may be limited to normodivergent subjects with normal mandibular incisor inclination and position. Subjects with initially proclined mandibular incisors should be closely monitored if treated with an RABP, as their teeth may become more proclined after treatment.

CONCLUSIONS

- A removable anterior bite plane could correct a deep bite in children by extrusion of the posterior teeth and proclination and intrusion of the mandibular incisors.
- Both the F + M and F − M groups achieved similar cephalometric changes. However, the rates of deep bite correction and mandibular molar extrusion were higher in the F + M group.
- The relationship between daily duration of wear and the rate of OB change can be partly explained by a positive exponential model.

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DISCLOSURE

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