

# Dentoskeletal Changes from Two Types of Anterior Bite Planes in Deep Bite Children: A Randomized Controlled Study

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## Abstract

This study aimed to compare the dentoskeletal changes after using anterior bite planes fabricated from acrylic resin (ABP) and thermoplastic materials (TBP) to correct deep bite in a group of children. Fifty-one deep bite patients (aged  $11.87 \pm 1.35$  years) were randomly allocated into an untreated control, ABP, and TBP groups. Cephalometric changes between before the treatment (T0) and the visit after normal overbite was achieved (T1) were analyzed ( $\alpha = .05$ ). Compared with the untreated control group at the average treatment duration of  $5.05 \pm 1.5$  months, significant changes in overbite and lower facial height in both treatment groups were observed ( $P < .05$ ). ABP and TBP reduced overbite by  $2.57 \pm 1.70$  mm and  $2.30 \pm 1.75$  mm, respectively ( $P \geq .05$ ). Lower facial height of ABP and TBP increased by  $2.60 \pm 2.50$  mm and  $1.90 \pm 2.25$  mm, respectively ( $P \geq .05$ ). Significant increases of the overjet and proclination of maxillary incisors were observed in the ABP group ( $P < .05$ ), while significant decreases of overjet and retroclination of maxillary incisors were found in the TBP group ( $P < .05$ ). Comparing the TBP group with the control and ABP groups, a significant reduction ( $P < .05$ ) was observed in both overjet and maxillary incisor inclination. In conclusion, ABP and TBP successfully alleviated deep bite. However, overjet and maxillary incisor inclination of the ABP group increased, while both parameters of TBP group decreased.

**Keywords:** Cephalometry, Child, Orthodontic appliances, Overbite, Prospective studies

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## Introduction

Deep bite is characterized by an excessive vertical overbite in the anterior region.<sup>1</sup> Baccetti *et al.* defined deep bite as a malocclusion where the overbite is greater than 4 mm and where the mandibular incisor crowns overlap the maxillary incisors vertically by more than 40%.<sup>2</sup> The prevalence of deep bite increases significantly from 5.8% to 18.4% from primary to early permanent dentition.<sup>3</sup> This

malocclusion is less commonly self-corrected from primary to early permanent dentition compared to anterior open bite, sagittal malocclusions, or posterior crossbite, and has a high tendency to relapse after orthodontic treatment.<sup>3,4</sup>

It is recommended to treat a deep bite early to prevent gingival trauma at the palatal surface of the maxillary incisors and attrition of mandibular incisors. Early treatment

can also prevent adverse effects on lateral and anterior mandibular movements during mastication and temporomandibular joint problems.<sup>3,5,6</sup> Delayed treatment of excessive overbite may later lead to skeletal sagittal discrepancy.<sup>7</sup> Correction of a deep bite in late mixed or early permanent dentition is apparently stable.<sup>8,9</sup>

The mode of treatment for a deep bite in growing patients is mainly extrusion of posterior teeth. Every 1.0 mm of posterior dental extrusion resulted in a bite opening of 2.0-2.5 mm in the incisal area.<sup>10</sup> A common appliance used to treat a deep bite in children is a removable anterior bite plane fabricated from acrylic resin material (ABP) (Fig. 1A) that provides mandibular posterior teeth extrusion.<sup>11,12</sup> The current modality is a clear thermoplastic anterior bite plane (TBP) that covers the clinical crowns of all maxillary teeth (Fig. 1B).<sup>13,14</sup> The TBP may be more comfortable than the ABP since it has no palatal tissue coverage, and it is more esthetically acceptable because it is transparent. Nevertheless, the two appliances have different retentive component designs, fabrication processes, hardness of materials, and crown coverage that may cause different skeletal and dental changes.

This study aimed to compare the skeletal and dental changes in a group of deep bite growing patients using either an ABP or a clear TBP. The null hypothesis was that there was no significant difference in the skeletal and dental changes between ABP and TBP.

## Materials and Methods

### Trial design and Any Changes after Trial Commencement

This three-arm, parallel randomized controlled trial study was approved by the Ethics Committee on Human Research of the Faculty of Dentistry, Prince of Songkla University (ethical approval No. EC6305-014-P-HR). The trial was registered at the Thai Clinical Trial Registry, under the identifier TCTR20201230001.

### Sample Size Calculation

The sample size was calculated by G\*Power (Version 3.1)<sup>15</sup> using parameters from a study on the comparison of overbite changes from the use of a removable anterior bite plane followed by fixed appliances and untreated

patients. The differences of mean overbite changes were -3.1 and -1.4. The differences of standard deviation were 1.3 mm and 1.5 mm. The level of significance was set at 0.05, and power of the test was 0.85.<sup>16</sup> The initial sample size was 14 per group. At a drop-out rate of 20 %, the final sample size was 17 per group.

### Participants, Eligibility Criteria, and Setting

The subjects were consecutively recruited from the Orthodontic Clinic, Dental Hospital, Faculty of Dentistry, Prince of Songkla University according to the following inclusion criteria: (1) dental deep bite (overbite > 40 % of clinical crown height of the mandibular incisors<sup>2</sup>), (2) overjet 1-5 mm, (3) Class I or mild Class II malocclusion, (4) late mixed dentition (9-13 years), (5) Class I or mild Class II skeletal relationship ( $1^\circ < ANB < 6^\circ$ ), and (6) hypodivergent or normodivergent pattern ( $SN-MP < 35^\circ$ ). The exclusion criteria were: (1) signs or symptoms of temporomandibular disorders, and (2) clinical absence of first molars or mandibular incisors.

### Randomization

The subjects were randomly allocated into three groups: untreated control, ABP, and TBP groups using the www.random.org web site for a list of generated numbers. Subjects in the control group were observed for skeletal and dental changes from lateral cephalograms for 6 months and were then treated with an orthodontic appliance. Subjects in the experimental groups were randomly allocated into either the ABP or TBP group. Before participating in this trial, all subjects and guardians were informed of the purpose and implications of the study and were required to sign consent forms. Two postgraduate students in the orthodontic clinic, under supervision of an orthodontist, treated the subjects.

### Interventions

**ABP Appliance:** The appliance included two Adam's clasps on the maxillary permanent first molars, a labial arch wire, and an acrylic coverage on the palate with an anterior bite plane in contact with the incisal edge of all four mandibular incisors (Fig. 1A).

**TBP Appliance:** The appliance was made of a 1.8 mm thick thermoplastic bilaminate material (Durasoft® pd - SCHEU-DENTAL GmbH, Iserlohn, Germany) composed of

polyethylene and polyurethane. The design of the appliance was modified based on previous studies 13,14 For dental cast preparation, plaster was applied to the palatal aspect of the maxillary anterior teeth and shaped to resemble the anterior bite plane of the ABP appliance. Additionally, rectangular plaster pieces measuring 1.5x4 mm were attached to the buccal surface of the first primary molar or first premolar teeth on both sides to create convex buttons on the outer surface of the appliance. These buttons served as “appliance removal helpers”. Patients were instructed to use their fingers to push these buttons occlusally for appliance removal, which prevented the appliance edge from tearing due to repetitive pulling.<sup>14</sup>

Following the vacuum thermoforming process, the thermo-plastic material was heated and compressed, resulting in a reduced thickness from 1.8 mm to an average of 0.5-0.8 mm on the posterior occlusal surface coverage. The appliance was trimmed and extended 2-3 mm beyond the gingival margin of all teeth (Fig. 1B).

The flat bite plane surface of both the ABP and TBP appliances contacted four mandibular incisors to create a 2-mm disocclusion at the first permanent molars. Subjects in the ABP and TBP groups were advised to wear the appliances full-time except during meals and tooth brushing. The subjects were examined monthly until a 2-mm of overbite was achieved.

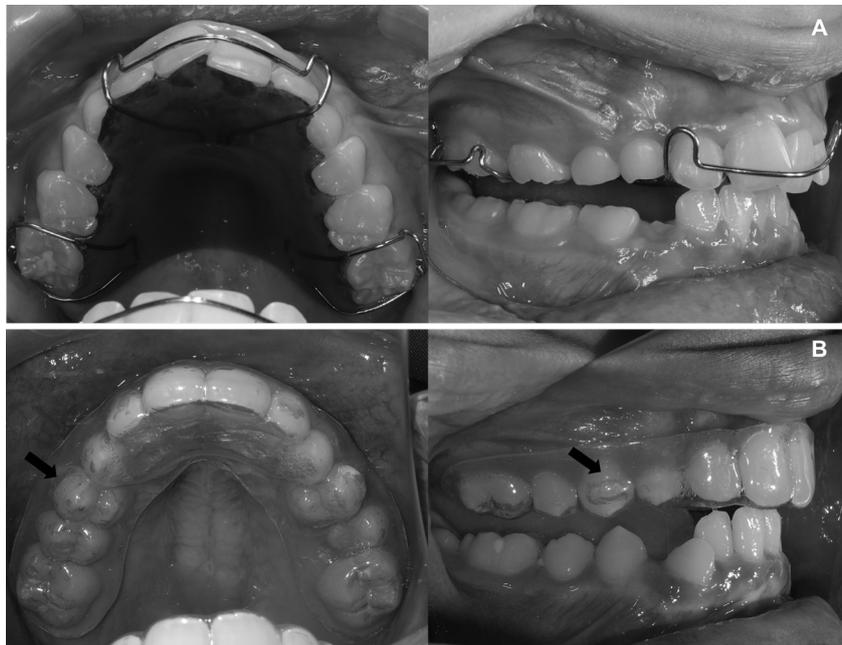


Figure 1 Occlusal (left) and lateral (right) views of the ABP (A) and TBP (B)

### Interim Analysis and Stopping Guidelines

If harm from a deep bite occurred in the control group, orthodontic treatment was immediately started. Subjects in the treatment groups whose overbite remained unchanged for 3 months<sup>17</sup> after the start of the study were to be withdrawn from the study and treated with other types of orthodontic appliances.

### Cephalometric Analysis

Lateral cephalograms were taken in all subjects. For the control group, lateral cephalograms of the control group were taken at the first visit ( $T_0$ ) and 6 months later

( $T_1$ ). Lateral cephalograms of the two experimental groups were taken before treatment ( $T_0$ ) and after achieving normal overbite ( $T_1$ ) with natural head position. The same cephalostat and cephalometric machine were used for all images.

Cephalometric measurements were modified based on the methods described by Forsberg<sup>18</sup> and Franchi *et al.*<sup>8</sup> (Fig. 2). Cephalometric images were digitized and analyzed by one researcher using Dolphin Imaging software version 11.9 (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). Landmarks for the  $T_0$  and  $T_1$  radiographs

of each patient were sequentially identified to reduce potential landmark identification error. Parameters were measured in distances and angles to evaluate skeletal and

dental changes (Fig. 2 and Table 1). Results were obtained from skeletal and dental changes in sagittal and vertical dimensions.

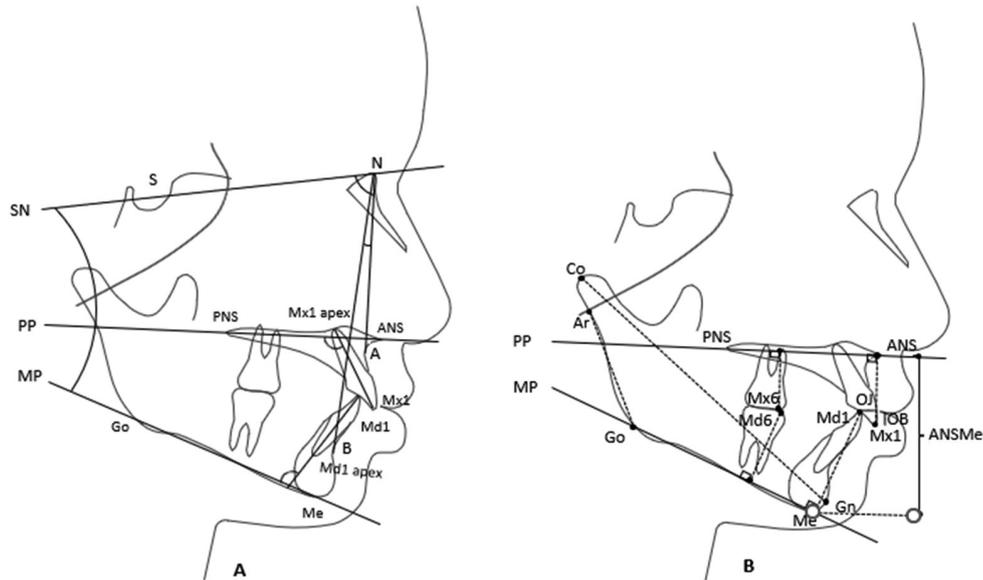


Figure 2 Angular (A) and linear (B) cephalometric measurements used in this study

Table 1 Cephalometric measurements (Fig. 2)

Measurement	Definition
Skeletal A-P	SNA (°) Sella-Nasion to A Point Angle
	SNB (°) Sella-Nasion to B Point Angle
	ANB (°) Angle between NA line and NB line
Skeletal Vertical	SNMP (°) Angle between SN plane and mandibular plane (Go-Me)
	ArGo (mm) Distance between Ar and Go
	CoGn (mm) Distance between Co and Gn
	ANSMc (mm) Distance measured from anterior nasal spine to menton
Dental	OB (mm) Vertical distance between the Mx1 and Md1
	OJ (mm) Horizontal distance between the Mx1 and Md1
	Mx1PP (°) Angle between the long axis of the maxillary incisor (Mx1 axis) and palatal plane (PP)
	Mx1perpPP (mm) Distance perpendicular to palatal plane to incisal tip of maxillary incisor
	Mx6perpPP (mm) Distance perpendicular to maxillary plane to mesiobuccal cusp of maxillary first molar
	Md1MP (°) Angle between the long axis of the mandibular incisor (Md1 axis) and mandibular plane (MP)
	Md1perpMP (mm) Distance perpendicular to mandibular plane to incisal tip of mandibular incisor
	Md6perpMP (mm) Distance perpendicular to mandibular plane to mesiobuccal cusp of mandibular first molar

The rates of mandibular molar extrusion and overbite correction in units of mm/month were determined by the amount of change (mm) divided by the observed duration (months).

**Blinding**

The operators and subjects were not blinded because of awareness of the appliance type. However, single blinding was accomplished when the researcher measured the lateral cephalogram data. All records were identified with an individual number of each subject to conceal the subject’s group allocation.

**Statistical Analysis**

The SPSS 25.0 software program (SPSS Inc, Chicago, IL, USA) was used for the statistical analysis. According to the Kolmogorov-Smirnov tests, the majority of variables were not normally distributed. Therefore, non-parametric statistics were applied. The median and interquartile range were used to present the average value of each parameter. Chi-square test was used to compare gender between groups. Wilcoxon signed rank tests were used to compare the cephalometric data between time points within groups. Kruskal-Wallis and pairwise comparisons were used to

evaluate the differences between the three groups. The significance level was set at 0.05.

**Error of Method**

To assess the reliability of the outcomes, 20 randomly selected patients had their cephalometric data retraced and remeasured after an interval of one month by the same investigator. Dahlberg’s formula and intraclass correlation coefficients were used to assess agreement.

**Results**

**Participant Flow**

A total of 65 children were assessed for eligibility. Fourteen children were excluded because they did not meet the inclusion criteria and two refused to participate. Thus, 51 patients, 30 males and 21 females; with a mean  $\pm$  SD age of  $11.52 \pm 1.38$  years were randomized in a 1:1:1 ratio to the control group, ABP group, and TBP group. No subjects dropped out during the study. The CONSORT diagram shows the flow of subjects assessed for randomization, allocation, treatment, and follow-up (Fig. 3).

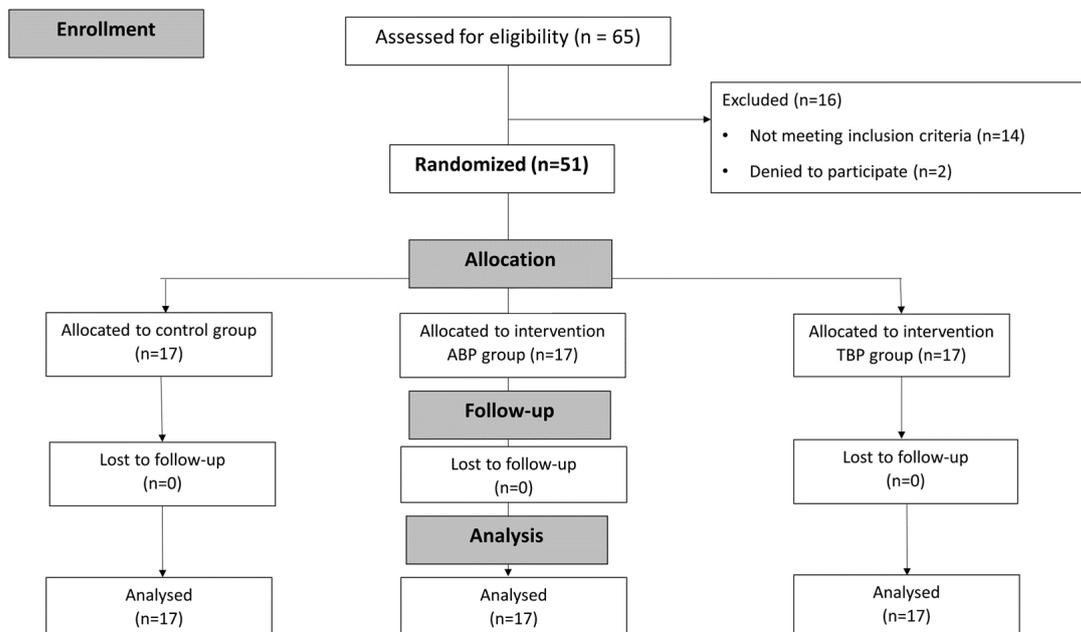


Figure 3 CONSORT flow diagram of the study

The measurement error for each parameter ranged from 0.01 - 0.24 mm and 0.13° - 0.38° for linear variables and angular variables, respectively. The intraclass correlation coefficient ranged from 0.83 - 0.97 for all measurements. The measurement errors and reliability values were acceptable.

Comparisons of baseline characteristics are presented in Table 2. No statistically significant difference in any parameter between the three groups was observed concerning gender, age, overbite, overjet, ANB, SNMP angle, maxillary or mandibular incisor inclinations ( $P > .05$ ).

No significant difference in the total observation/treatment times was found between the three groups ( $P > .05$ ). The mandibular extrusion and overbite correction rates were not statistically significantly different between the ABP and TBP groups ( $P < .001$ ) (Table 3). Deep bites in the ABP and the TBP groups were completely corrected with average treatment durations of  $5.00 \pm 2.50$  and  $5.10 \pm 3.00$  months, respectively. No harmful effects occurred in any subject. The intention to treat principle was used to analyze the data.

**Table 2** Comparison of baseline characteristics at pre-treatment

Variables	Control (n = 17)		ABP (n = 17)		TBP (n = 17)		P Value
	Median	IQR <sup>a</sup>	Median	IQR	Median	IQR	
N (boys : girls)	11 : 6		10 : 7		9 : 8		.784 <sup>b</sup>
Age (y)	11.66	1.33	11.87	1.00	11.15	1.74	.298 <sup>c</sup>
Overbite (mm)	4.40	1.90	4.50	1.80	4.20	1.80	.907 <sup>c</sup>
Overjet (mm)	4.50	1.35	4.50	1.45	4.80	1.60	.279 <sup>c</sup>
ANB (°)	3.14	1.89	4.37	1.20	3.44	2.47	.093 <sup>c</sup>
SNMP (°)	27.09	6.09	25.87	5.40	27.25	5.65	.078 <sup>c</sup>
Mx1PP (°)	113.00	15.25	116.10	11.80	118.70	6.45	.377 <sup>c</sup>
Md1MP (°)	95.50	6.00	96.30	9.20	94.20	7.35	.603 <sup>c</sup>

ABP: acrylic resin bite plane, TBP: thermoplastic bite plane; <sup>a</sup>IQR: interquartile range.

<sup>b</sup> P Value of Chi-square. <sup>c</sup> P Value of by Kruskal-Wallis tests.

**Table 3** Comparison of total observation/treatment time, mandibular molar extrusion rate and overbite correction rate among the three groups

Variables	Control (n=17)		ABP (n=17)		TBP (n=17)		P Value
	Median	IQR	Median	IQR	Median	IQR	
Observation/Tx time (month)	5.80	1.00	5.00	2.50	5.10	3.00	.149
Md6 extrusion rate (mm/month)	0.10 <sup>a</sup>	0.18	0.37 <sup>b</sup>	0.41	0.30 <sup>b</sup>	0.45	.004**
Overbite correction rate (mm/month)	0.01 <sup>a</sup>	0.19	-0.57 <sup>b</sup>	0.50	-0.60 <sup>b</sup>	0.52	.000***

ABP: acrylic resin bite plane, TBP: clear thermoplastic bite plane, IQR: interquartile range. \*\*  $P < .01$ , \*\*\*  $P < .001$ ; Kruskal-Wallis tests.

Groups with the same letter are not significantly different ( $P > .05$ )

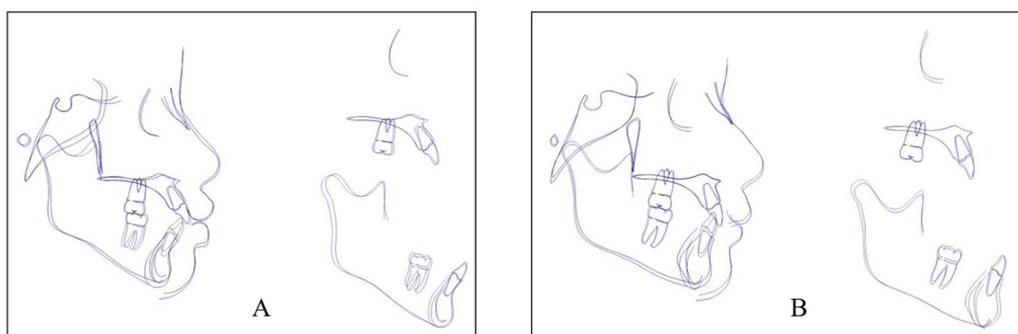
Table 4 Cephalometric measurements before treatment (T<sub>0</sub>) and after (T<sub>1</sub>) observation period of control group and before (T<sub>0</sub>) and after (T<sub>1</sub>) achieving normal overbite in the ABP and TBP groups

Variables	Control (n=17)						ABP (n=17)						TBP (n=17)					
	T <sub>0</sub>			T <sub>1</sub>			T <sub>0</sub>			T <sub>1</sub>			T <sub>0</sub>			T <sub>1</sub>		
	Median	IQR	P value	Median	IQR	P value	Median	IQR	P value	Median	IQR	P value	Median	IQR	P value	Median	IQR	P value
Skeletal A-P	SNA (°)	79.50	9.05	79.70	9.00	.200	81.40	5.35	82.20	5.90	.593	82.90	4.90	83.90	6.20	.120		
	SNB (°)	77.60	7.80	78.50	8.45	.100	78.80	4.05	79.00	4.80	.717	78.70	3.45	78.20	4.70	.330		
	ANB (°)	3.14	1.89	3.60	2.70	.954	4.37	1.20	3.20	2.70	.943	3.50	3.60	2.80	3.65	.836		
Skeletal vertical	SNMP (°)	26.70	6.35	25.70	7.15	.448	27.50	6.90	28.10	7.65	.053	27.30	10.30	28.60	7.95	.062		
	ArGo (mm)	35.80	5.10	37.80	6.10	.001**	37.00	6.95	38.60	6.50	.000***	36.80	5.90	37.20	5.95	.041*		
	CoGn (mm)	99.20	7.90	101.00	8.95	.002**	101.00	6.80	102.80	7.10	.001**	100.70	8.25	102.30	9.85	.001**		
Dental	ANSMe(mm)	57.10	2.85	54.90	7.30	.448	57.70	4.45	60.40	4.50	.000***	57.80	6.10	59.60	5.50	.000***		
	OB (mm)	4.40	1.90	4.40	1.50	.123	4.50	1.80	1.80	0.95	.000***	4.20	1.80	2.20	1.75	.000***		
	OJ (mm)	4.50	1.35	4.80	1.55	.194	4.50	1.45	4.95	1.00	.459	4.80	1.60	4.10	1.00	.002**		
Dental	Mx1PP (°)	113.00	15.25	114.40	15.20	.365	116.10	11.80	118.00	13.80	.044*	118.70	5.77	117.50	6.75	.053*		
	Mx1perPP (mm)	25.40	2.70	25.90	2.70	.887	26.00	3.55	27.40	4.65	.836	24.80	4.00	24.50	3.80	.740		
	Mx6perPP (mm)	17.70	3.05	18.10	2.65	.111	18.90	3.90	19.10	2.45	.044*	17.00	4.15	19.10	3.80	.006**		
	Md1MP (°)	95.50	6.00	94.20	9.05	.393	96.30	9.20	96.10	9.40	.266	94.20	7.35	96.70	10.20	.068		
	Md1perMP (mm)	36.80	2.65	37.70	3.10	.042*	37.50	2.00	37.80	1.95	.063	37.30	3.25	36.20	3.70	.052		
	Md6perMP (mm)	26.60	4.40	27.20	3.80	.064	27.10	2.85	28.75	1.98	.001**	26.50	2.40	27.90	2.85	.007**		

ABP: acrylic resin bite plane, TBP: thermoplastic bite plane, IQR: interquartile range. \* P < .05, \*\* P < .01, \*\*\* P < .001; Wilcoxon matched-pairs signed rank tests.

Within group comparisons, significant increases in the ramus height (ArGo) and mandibular length (CoGn) were found in all groups ( $P < .05$ ). Significant increases in lower facial height (ANSMe) in the ABP and TBP groups were 2.60 mm and 1.90 mm, respectively ( $P < .05$ ). For maxillary incisor inclination, the Mx1PP significantly increased by  $1.9^\circ$  in the ABP group ( $P < .05$ ). However, in the TBP group, the Mx1PP significantly decreased by  $-1.2^\circ$  ( $P < .05$ ). In both

treatment groups, a significant decrease in overbite was observed ( $P < .001$ ). Maxillary and mandibular molar extrusions were shown in the ABP and TBP groups ( $P < .05$ ), whereas these molar positions remained unchanged in the control group ( $P \geq .05$ ) (Tables 4). Examples of dentoskeletal changes according to lateral cephalometric superimposition between  $T_0$  and  $T_1$  in an ABP subject and a TBP subject are presented in Figure 4.



**Figure 4** Cranial base, maxilla and mandible superimposition on the stable structures in an ABP subject (A) and a TBP subject (B).

Significant difference was not observed among the three groups for any sagittal skeletal cephalometric variable ( $P \geq .05$ ) (Table 5). Vertically, both treatment groups induced a significant increase in lower facial height compared to the untreated control group ( $P < .05$ ). Dentally, overbite was reduced in ABP and TBP groups by  $2.57 \pm 1.70$  mm and  $2.30 \pm 1.75$  mm, respectively ( $P > .05$ ). The changes were significantly different from the control group ( $P < .000$ ). Similarly, mandibular molar extrusions were significantly greater in both treatment groups compared with the control

group ( $P < .05$ ). Mandibular incisor inclination and mandibular incisal vertical change were not significantly different between the treatment groups and the untreated control group ( $P > .05$ ). Overjet was significantly reduced in the TBP group ( $-0.7$  mm), which was significantly different from the control and ABP groups ( $P < .05$ ). The maxillary incisors of the TBP group were retroclined more than in the control and ABP groups ( $P < .05$ ), whereas changes in maxillary inclination of the ABP group were significantly proclined more than in the control and TBP groups ( $P < .05$ ) (Table 5).

**Table 5** Comparison of median and interquartile range of cephalometric value changes between the three groups

Variables		Control (n=17)		ABP (n=17)		TBP (n=17)		P value
		Median	IQR	Median	IQR	Median	IQR	
Skeletal A-P	SNA ( $^\circ$ )	0.70	1.25	0.00	1.45	0.30	1.40	.201
	SNB ( $^\circ$ )	0.74	0.85	0.02	2.15	0.60	1.20	.181
	ANB ( $^\circ$ )	0.10	0.70	0.10	1.15	-0.10	1.20	.781
Skeletal vertical	SNMP ( $^\circ$ )	-0.10	1.90	0.30	2.25	0.50	1.60	.058
	ArGo ( $^\circ$ )	1.80	2.30	1.20	2.35	1.00	3.05	.397
	CoGn (mm)	1.40	2.05	1.90	3.15	1.50	2.95	.727
	ANSMe (mm)	0.40 <sup>a</sup>	2.00	2.60 <sup>b</sup>	2.50	1.90 <sup>b</sup>	2.25	.000***

**Table 5** Comparison of median and interquartile range of cephalometric value changes between the three groups (cont.)

Variables		Control (n=17)		ABP (n=17)		TBP (n=17)		P value
		Median	IQR	Median	IQR	Median	IQR	
Dental	OB (mm)	0.10 <sup>a</sup>	0.90	-2.57 <sup>b</sup>	1.70	-2.30 <sup>b</sup>	1.75	.000***
	OJ (mm)	0.20 <sup>a</sup>	0.80	0.45 <sup>a</sup>	1.45	-0.70 <sup>b</sup>	1.35	.003**
	Mx1PP (°)	0.00 <sup>ab</sup>	2.15	0.70 <sup>a</sup>	3.80	-0.10 <sup>b</sup>	4.20	.028*
	Mx1perpPP (mm)	0.00	1.30	0.00	1.70	-0.20	1.20	.919
	Mx6perpPP (mm)	0.30	1.00	0.90	2.10	1.30	1.35	.059
	Md1MP (°)	-1.30	4.10	2.60	4.87	1.70	2.25	.093
	Md1perpMP (mm)	0.04	1.30	0.40	2.95	0.57	2.05	.901
	Md6perpMP (mm)	0.40 <sup>a</sup>	1.15	1.60 <sup>b</sup>	1.45	0.90 <sup>b</sup>	1.40	.025*

ABP: acrylic resin bite plane, TBP: thermoplastic bite plane, IQR: interquartile range.

T0: before treatment, T1: after achieving normal overbite

\* P < .05, \*\* P < .005, \*\*\* P < .001 by Kruskal-Wallis tests.

Groups with the same letter are not significantly different (P > .05)

## Discussion

This randomized controlled trial demonstrated that both ABP and TBP were successful in correcting a deep bite at comparable rates. The primary mechanism of deep bite correction was through the extrusion of mandibular posterior teeth. After accounting for the amount of mandibular posterior dentoalveolar growth in the untreated group, the net mandibular molar extrusion due to the application of ABP and TBP was approximately 1.2 mm and 0.5 mm, respectively. Although not statistically significant and assuming similar masticatory function, the slightly larger amount of mandibular molar extrusion in the ABP group compared to the TBP group was possibly due to the posterior occlusal surface coverage of the TBP appliance, which had a thickness of about 0.5-0.8 mm due to the heated vacuum fabrication process and may limit the amount of mandibular molar extrusion.

Mandibular incisor inclinations were not affected by the anterior bite planes, which is in accordance with the results from previous studies.<sup>8,18</sup> This could be because the biting force acting against the anterior bite plane is transmitted along the axis of the mandibular incisors. Therefore, a removable anterior bite plane may provide an advantage over fixed appliances for deep bite correction

in patients whose mandibular incisor inclination needs to be controlled. Fixed appliances exert intrusive forces labially to the center of resistance of the roots, which therefore inevitably produce labial proclination.

The TBP group showed retroclination of the maxillary incisors, while the ABP group exhibited proclination. An explanation for this is based on the material characteristics and design differences between the two appliances. The TBP thermoplastic material has a lower modulus of elasticity than the ABP acrylic resin, which results in being squashed down when pushed.<sup>19,20</sup> Furthermore, the TBP appliance fully covers the labial surface of the maxillary incisors, while the ABP appliance has only a labial bow wire contacting the labial surface of the maxillary incisors at the middle third of the crown height. When biting on the TBP bite plane, the thermoplastic material is compressed towards the palatal tissue, which pulls the labial coverage of the appliance palatally, thus leading to palatal tipping of the maxillary incisors.<sup>13</sup> In contrast, when biting on the hard acrylic surface of the ABP, the force is transmitted from the bite plane to the palatal surface of the maxillary incisors, which eventually causes labial tipping. If the tipping force is incisal to the labial bow wire, a couple force is

created and enhances the tipping effect.<sup>21,22</sup> While there was a noticeable change in maxillary incisor inclination in both the ABP and TBP groups, no significant difference was observed in the vertical movement of the maxillary incisors within or between the groups. This suggests that neither the ABP nor TBP designs has an extrusive or intrusive effect on the maxillary incisors.

Skeletally, both the ABP and TBP groups showed a significant increase in lower facial height (ANS-Me), while the mandibular plane angle (SN-MP) remained unchanged. Previous studies also observed that growing patients were able to maintain their mandibular plane angles after deep bite treatment. This may be due to compensatory vertical ramal growth and condylar growth, which was suggested in previous studies.<sup>8,23,24</sup>

Our study followed the intention-to-treat principle, which reduces the likelihood of overestimating results by including non-compliant subjects while recognizing that such events may occur in the clinical setting.<sup>25</sup> However, there are some limitations to consider. The generalizability of our findings is limited to growing patients with skeletal Class I or mild skeletal Class II, deep bite, and normal maxillary and mandibular incisor inclination. Additionally, our results cannot be extrapolated to fixed anterior bite planes or the correction of deep bite with fixed appliances or other designs. Although certain dentoskeletal changes were observed during the 6-month study period, it is important to note that this duration may not be sufficient to fully capture the complete changes resulting from the application of the anterior bite plane. Consequently, a long-term follow-up is imperative to comprehensively investigate the overall skeletal changes and gain a deeper understanding of the treatment's effectiveness and stability over an extended period of time. For further studies, the study sample should be increased to avoid type II error. Since patient compliance is a key factor in the success of removable appliances for correcting malocclusion, embedding a time recording sensor into the appliance to monitor the exact duration of wear may provide useful information on the effect of compliance on deep bite correction.

In clinical practice, the ABP may be more appropriate for patients who require proclination of their maxillary incisors, for example in Class II division 2 patients with retroclined maxillary incisors or those with increased tooth-to-lip relationship. Conversely, the TBP may be more appropriate for patients who need retroclination of the maxillary incisors such as those with Class II division 1 malocclusion with protruded incisors and increased overjet.

## Conclusion

Both ABP and TBP were effective in correcting deep bite in children within a similar treatment duration. The correction of deep bite was primarily achieved through mandibular molar extrusion. The use of ABP resulted in proclination of the maxillary incisors, while the TBP caused retroclination of the maxillary incisors.

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