

# Dentoalveolar Effects of Miniscrew-Assisted Transpalatal Arch versus Clear Aligner in Anterior Open Bite: A Prospective Cephalometric Study

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## Abstract

**Background:** Treatment of anterior open bite commonly involves anterior extrusion, posterior intrusion, or both. Miniscrew-assisted transpalatal arch (MT) mechanics have been used for maxillary posterior intrusion, whereas clear aligner (CA) therapy has become popular because of its esthetic advantages. However, the mechanics of open-bite correction with clear aligners remain controversial. **Objective:** To compare dentoalveolar changes following anterior open bite treatment with MT mechanics versus CA therapy using lateral cephalometric analysis. **Materials and methods:** In this single-center prospective cohort study, 34 adults with anterior open bite (0–4 mm) were treated and evaluated: 15 in the MT group and 19 in the CA group. Lateral cephalograms were obtained at pretreatment (T0) and after 6 months (T1). Within- and between-group dentoalveolar changes were analyzed using paired and independent *t*-tests ( $P < 0.05$ ). **Results:** Both treatments significantly reduced the anterior open bite, with no significant between-group difference in overbite change (MT = 3.17 mm, CA = 3.11 mm). MT produced greater maxillary first molar intrusion than CA (U6-PP: MT = 2.01 mm, CA = 0.82 mm). Only the CA group showed a significant increase in anterior dental height (ADH: CA = +1.93 mm). CA showed greater decreases in U1-NA angulation (CA =  $-5.87^\circ$ , MT =  $+2.67^\circ$ ) and U1-NA distance (CA = -1.98 mm, MT = +0.76 mm). Overjet decreased more with CA ( $P < 0.05$ ). **Conclusion:** MT with partial fixed anterior archwire primarily produced posterior intrusion and minimal incisor changes, whereas CA predominantly produced maxillary incisor extrusion and retroclination with limited molar intrusion.

**Keywords:** Anterior open bite, Clear aligner, Dentoalveolar change, Miniscrew

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## Introduction

An anterior open bite is characterized by a lack of vertical overlap between the incisal edges of the maxillary and mandibular anterior teeth.<sup>1</sup> The etiology of anterior open bite is multifactorial, involving skeletal, dental, soft tissue, and habitual factors. Therefore, multiple treatment strategies have been developed according to the underlying etiologies and dentoskeletal characteristics of each patient.<sup>2</sup> Anterior open bite can adversely affect smile esthetics, speech function, swallowing due to lingual interposition, and incisal biting function.<sup>1,3-7</sup> Various treatment methods aim to correct anterior open bite by eliminating etiologic factors, improving function and esthetics, and promoting treatment stability.<sup>8-11</sup> Treatment modalities are selected based on the patient's age and the underlying etiology. These may include correction of parafunctional habits such as tongue thrusting, interceptive treatment in growing patients, orthodontic camouflage treatment for mild to moderate anterior open bite, and a combined orthodontic-surgical approach for severe skeletal problems.<sup>12</sup>

In non-growing patients with mild to moderate anterior open bite, treatment modalities include camouflage approaches involving incisors extrusion, posterior teeth intrusion, or a combination of both. In patients requiring premolar extraction due to space deficiency or anterior protrusion, the drawbridge effect may also contribute to open bite correction.<sup>12</sup>

Skeletal anchorage provides absolute anchorage for posterior teeth intrusion, followed by counterclockwise mandibular rotation, thereby contributing to anterior open bite reduction.<sup>13-16</sup> Retrospective studies have reported an association between maxillary molar intrusion and reduction of anterior open bite.<sup>10,13-16</sup> Several methods have been proposed to prevent transverse tipping of maxillary posterior teeth during intrusion, including bilateral miniscrew placement combined with a continuous archwire and application of intrusive forces through the

center of resistance (CRe) of the posterior segments.<sup>17</sup> However, without posterior segment consolidation, these methods require at least two miniscrews, one on each side, to achieve posterior tooth intrusion. Moreover, the magnitude of the vertical intrusive force on each side must be equal. The transpalatal arch (TPA) has been widely used for anchorage control in orthodontic treatment. The use of a miniscrew combined with TPA<sup>15,18</sup> (a miniscrew-assisted TPA) helps consolidate the posterior segment during intrusion, prevent transverse tipping of the molars, and reduce the need for force calibration at each activation, while requiring only a single palatal miniscrew. However, full-fixed orthodontic appliances may be necessary for other mechanics, such as leveling and aligning the entire arch following maxillary posterior teeth intrusion.<sup>13</sup>

Recently, clear aligners have been widely used for the treatment of anterior open bite because of their esthetic advantages and avoidance of miniscrew placement. Previous studies on clear aligner treatment for anterior open bite correction have reported varying tooth movement mechanics, including anterior extrusion and molar intrusion. Although some aligner protocols have demonstrated successful anterior teeth extrusion, the effectiveness of posterior teeth intrusion remains controversial.<sup>19-24</sup> Therefore, further optimization of aligner protocols is required to achieve predictable outcomes.

Masticatory exercises have been recommended as an adjunctive treatment for open bite malocclusion, which is often associated with reduced masticatory muscle function. These exercises may improve vertical control and reduce aberrant vertical growth patterns. Previous studies incorporating squeezing (clenching) during clear aligner therapy have also reported increased bite force in anterior open bite patients.<sup>25</sup> Therefore, the present clear aligner protocol with squeezing exercises was designed based on these biomechanical considerations to enhance vertical control and promote favorable posterior dentoalveolar

changes. This study aimed to compare dentoalveolar changes produced by two different mechanics, anterior teeth extrusion and posterior teeth intrusion, to provide clinicians with information for selecting appropriate treatment approaches for anterior open bite.

## Materials and methods

### Study design, setting, participants, and criteria

This study was a single-center prospective cohort study. The participants were adult patients with anterior open bite, aged 18–35 years, who met the following inclusion criteria: 1) anterior dental open bite of 0–4 mm, measured from canine to canine; 2) incisal show at rest of 0–2 mm; 3) normal smile line; 4) skeletal

Class I or mild Class II relationship ( $ANB = 0-5^\circ$ ); 5) hyperdivergent facial pattern ( $SN-MP = 33-39^\circ$ ); and 6) available lateral cephalograms at pretreatment (T0) and after 6 months of treatment (T1).

The exclusion criteria included: 1) loss of any maxillary posterior teeth except third molars; 2) anterior crossbite; 3) transverse discrepancy; 4) moderate to severe crowding (space deficiency  $> 7$  mm); 5) history of dentoalveolar trauma; 6) neuromuscular or temporomandibular disorders; 7) craniofacial deformities; 8) poor compliance; and 9) use of medications or presence of systemic diseases affecting tooth movement. A total of 34 patients were included: 15 in the MT group and 19 in the CA group.

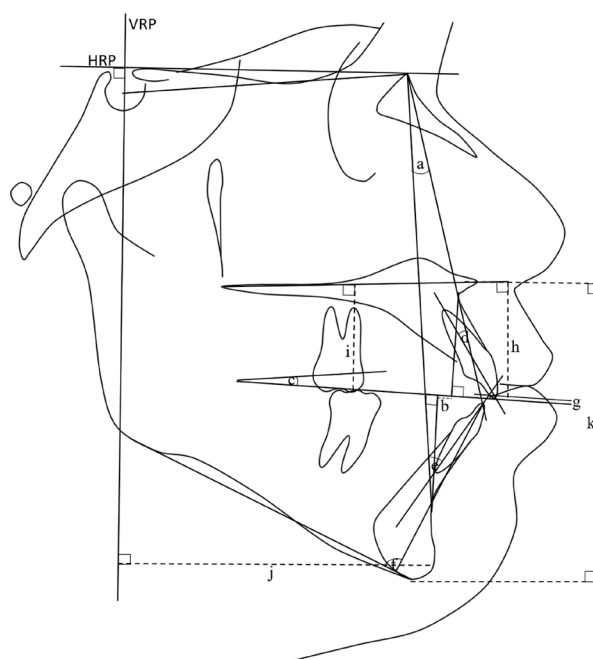


**Figure 1** Definition of cephalometric measurements used in this study: ANB, A point-Nasion-B point angle (a); Wits appraisal, the distance between the perpendicular projections of points A and B on the functional occlusal plane (b); OP-SN, the angle between the functional occlusal plane and the SN plane (c); U1-NA, the angle between the long axis of the maxillary incisor and the Nasion-A line (d); L1-NB, the angle between the long axis of the mandibular incisor and the Nasion-B line (e); L1-MP, the angle between the long axis of the mandibular incisor and the mandibular plane (f); U1-OP, the perpendicular distance from the maxillary incisor edge to the functional occlusal plane (g); ADH, anterior dental height, the perpendicular distance from the maxillary incisor edge to the palatal plane (h); U6-PP, the perpendicular distance from the mesial cusp tip of the maxillary first molar to the palatal plane (i); Pg-VRP, the perpendicular distance from Pogonion to the vertical reference plane (VRP) (j); and LAFH, lower anterior facial height, defined as the vertical distance from the anterior nasal spine to Menton (k).

## Outcomes

The primary outcomes of this study were the amount of maxillary molar intrusion, measured as the change in the vertical position of the maxillary first molar relative to the palatal plane (U6-PP), and overbite change between T0 and T1 (Figure 1).

The secondary outcomes included changes in incisor position and inclination (U1-NA), anterior dental height (ADH), the distance from the maxillary incisor edge to the functional occlusal plane (U1-OP), the angle between the functional occlusal plane and the SN plane (OP-SN), and overjet (Figure 1). The functional occlusal plane was defined as the line connecting the midpoint of functional intercuspation of the first premolars and the midpoint of the first molars.

## Power analysis and sample size

Sample size calculation was performed using G\*Power (version 3.1.9.4; Franz Faul, Kiel University, Kiel, Germany) based on the primary outcome of maxillary molar intrusion (U6-PP).<sup>22</sup> With a significance level of 0.05 ( $\alpha = 0.05$ ) and statistical power of 80 % ( $1 - \beta = 0.80$ ), 12 patients were required per group. Considering an estimated dropout rate of approximately 20 % per group, the final sample size was set at a minimum of 15 patients per group and a total sample size of at least 30 patients. The participants were recruited from patients attending the Department of Orthodontics, Faculty of Dentistry, Prince of Songkla University. Quota sampling was used, and recruitment continued until the required number of participants with predefined characteristics was reached. All participants were subsequently screened according to the inclusion and exclusion criteria, and only eligible individuals were included.

## Treatment protocol in MT group

The protocol for the MT group was modified from Tassanapanont et al.<sup>15</sup> A miniscrew, 2.0 mm in diameter and 6.0 mm in length (AbsoAnchor, Dentos, Daegu, Korea), was placed in the mid-palatal area in the mesial region of the maxillary first molar under local anesthesia. The TPA was fabricated with

a 3.0-mm offset from the palate to preserve vertical space for intrusion, and hooks were soldered to the molar bands on the palatal side to engage the nickel-titanium (NiTi) closed-coil springs during intrusion. Brackets and tubes (0.018-inch slot height; Roth™ system) were placed on the maxillary posterior teeth, and sectional 0.017 × 0.025-inch stainless steel wires were bent to be passively insert in the slots of the maxillary posterior teeth without force. The NiTi closed-coil springs were tied from

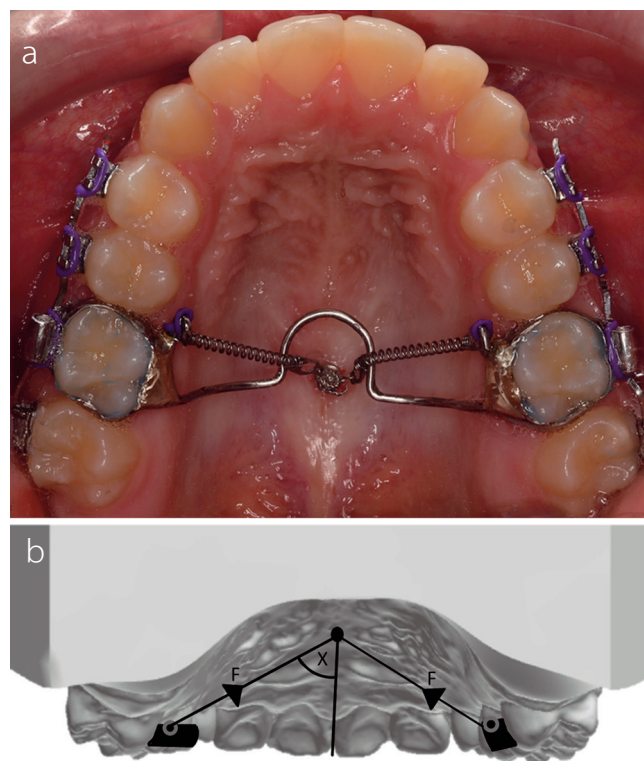


**Figure 2** Image of a miniscrew-assisted transpalatal arch. (a) The posterior segment was consolidated to prevent tipping of the posterior teeth. Nickel-titanium (NiTi) closed-coil springs were engaged from the miniscrew to the hooks on the transpalatal arch to generate constant intrusive forces for maxillary posterior teeth intrusion. The protocol was modified from Tassanapanont et al.<sup>15</sup> (b) The resultant intrusive force from each NiTi closed-coil spring was calculated using the formula  $F(\sin x^\circ) = 150$  grams ( $F$  = the magnitude of force;  $x$  = the angle between NiTi closed-coil spring and the vertical line).

the miniscrew to the hooks on the TPA bilaterally to generate the intrusive forces. Premature contact at the anterior teeth that occurred during molar intrusion was corrected using an anterior segmented archwire with pre-adjusted edgewise Roth™ system appliance with 0.018-inch bracket slots on the maxillary anterior teeth.

The magnitude of the resultant intrusive force from each NiTi closed-coil spring was controlled at 150 grams/side with force calibration at 3-week interval. The force was calculated using the formula:  $F(\sin x^\circ) = 150 \text{ grams}$  ( $F$  = magnitude of force;  $x$  = the angle between NiTi closed-coil spring and the vertical line) (Figures 2a, 2b).

### Treatment protocol in CA group

A custom-made CA was fabricated entirely in-office using an intraoral scan. Stereolithography (STL) files from the intraoral scanner (TRIOS 3, 3Shape, Copenhagen, Denmark) were imported into the 3Shape OrthoAnalyzer program. The maxillary anterior teeth were set up to extrude 0.2 mm/aligner. A beveled horizontal rectangular attachment was designed on the maxillary anterior teeth from canine to canine (Figures 3a, 3b). A model was printed using a 3D printer (Asiga Pro 4K, Asiga, Sydney, Australia). The CA was fabricated from a 1-mm thick Duran thermoplastic sheet. Patients were instructed to wear the CA for at least 22 hours/day with a 3-week change interval, and to perform squeezing exercises while wearing the CA. The exercise protocol was modified from English and Olfert (2005); briefly, patients were asked to perform a series of six isometric clenches (clenching as hard as possible without pain) on the clear aligner for 5 seconds, followed by 5 seconds of rest, at least 5 times a day (or as often as possible throughout the day). During the 6-month observation period, no mandibular appliances or other active orthodontic interventions were applied to the mandibular arch in either group.

### Cephalometric analysis

All lateral cephalograms were taken with the same cephalostat and cephalometric machine at

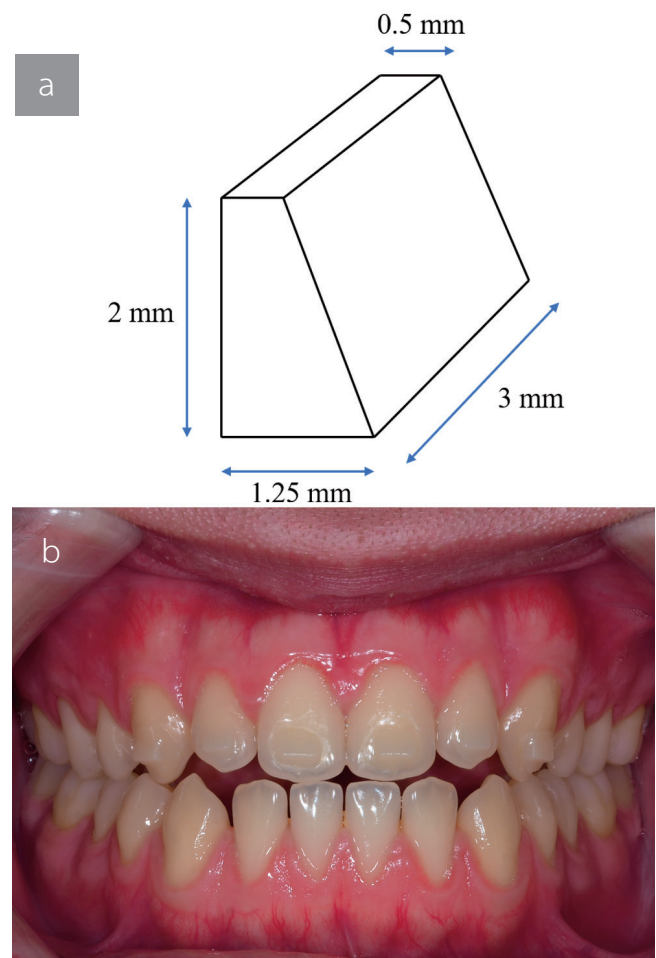


**Figure 3** Images of beveled horizontal rectangular attachments placed on the maxillary anterior teeth. (a) The attachment design consisted of 0.5-mm thickness on the gingival side; 1.25-mm thick toward the occlusal surface; with dimensions of 3 × 2 mm (width and height). Reproduced from Withayanukonkij et al.<sup>24</sup> (b) An intraoral photograph showing the position and shape of the attachments.

T0 and T1 for all subjects. Natural head position was established for standardization. The cephalograms were digitized and analyzed using Dolphin Imaging software (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA). All cephalometric landmarks were located and measured by one researcher after intra-observer reliability testing. Ten lateral cephalograms were randomly selected and remeasured by the same investigator after a 2-week interval to assess measurement errors. The measurement error was calculated by Dahlberg's

formula. The mean error was 0.13–0.18 mm for linear measurements and 0.11–0.16° for angular measurements. Intra-observer reliability, assessed using the intraclass correlation coefficient (ICC), was 0.94–0.97 for all cephalometric measurements, which indicated excellent reliability.

## Statistical analysis

All data were analyzed with SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Means and standard deviations were calculated. The normality of the distributions of all variables was tested using the Shapiro-Wilk test; most data showed a normal distribution. Log transformation was applied to variables with a non-normal distribution prior to statistical comparison. The Chi-square test was used to determine the distribution of gender between the two groups. The independent *t*-tests were used to compare pretreatment data between groups at T0 and to compare the difference in cephalometric parameters (T1–T0) between the MT and CA groups. The paired *t*-tests were used to compare cephalometric parameters within each group between T0 and T1. The significance level adopted in this study was 5 % ( $P$  value < 0.05).

## Results

Thirty-four subjects (9 males and 25 females) with a mean age of  $24.97 \pm 5.87$  years were recruited for this study. The MT group consisted of 15 patients (2 males and 13 females) and the CA group consisted of 19 patients (7 males and 12 females). There was no significant difference in gender distribution between the MT and CA groups ( $P$  value = 0.12) (Table 1).

Comparisons of cephalometric parameters between the MT and CA groups were performed at pretreatment (T0), after 6 months of treatment (T1), and for the changes from T0 to T1 (Table 2). Significant maxillary molar intrusion (U6-PP) was observed in both groups:  $2.01 \pm 0.22$  mm in the MT group and  $0.82 \pm 0.12$  mm in the CA group. The MT group

demonstrated 1.19 mm greater molar intrusion than the CA group ( $P$  value < 0.001).

Overbite increased significantly in both groups. Mean overbite changes were  $3.17 \pm 0.44$  mm in the MT group and  $3.11 \pm 0.42$  mm in the CA group ( $P$  value < 0.001), with no significant difference between groups ( $P$  value > 0.05).

The position and inclination of the maxillary incisors, assessed by U1-NA angulation and U1-NA distance, changed significantly in both groups. In the CA group, U1-NA angulation and U1-NA distance decreased by  $5.87 \pm 3.60^\circ$  and  $1.98 \pm 1.14$  mm, respectively ( $P$  value < 0.001). In contrast, in the MT group, U1-NA angulation and U1-NA distance increased by  $2.67 \pm 4.43^\circ$  ( $P$  value = 0.050) and  $0.76 \pm 1.19$  mm ( $P$  value = 0.027), respectively. The between-group differences were  $8.55^\circ$  for U1-NA angulation and 2.74 mm for U1-NA distance ( $P$  value < 0.001).

In the CA group, anterior dental height (ADH) increased significantly by  $1.93 \pm 0.38$  mm, which was 1.71 mm greater than that in the MT group ( $P$  value < 0.001).

The distance from the maxillary incisor edge to the functional occlusal plane (U1-OP) decreased in both groups ( $1.31 \pm 0.51$  mm in the MT and  $2.01 \pm 0.43$  mm in the CA). The between-group difference was 0.69 mm and was statistically significant ( $P$  value < 0.001).

The OP-SN angle increased in both groups, with a greater increase in the MT group ( $3.98 \pm 1.24^\circ$ ) than in the CA group ( $1.09 \pm 0.53^\circ$ ). The between-group difference was  $2.89^\circ$ , which was statistically significant ( $P$  value < 0.001).

Overjet decreased significantly in the CA group by  $0.76 \pm 0.35$  mm ( $P$  value < 0.001). Compared with the MT group, the reduction in overjet was significantly greater in the CA group by 0.58 mm ( $P$  value = 0.002).

The interincisal angle increased significantly in both groups, by  $5.49 \pm 2.91^\circ$  in the CA group ( $P$  value < 0.001) and by  $3.05 \pm 3.45^\circ$  in the MT group

( $P$  value = 0.004). The increase was significantly greater in the CA group than in the MT group by  $2.44^\circ$  ( $P$  value < 0.001).

ANB showed a significant decrease only in the MT group ( $-1.38 \pm 0.64^\circ$ ;  $P$  value < 0.001).

Wits appraisal, representing the maxillomandibular relationship relative to the functional occlusal plane, also decreased significantly only in the MT group ( $-2.26 \pm 1.87$  mm;  $P$  value < 0.001).

**Table 1** Comparison of gender, and cephalometric parameters between the MT and CA groups at pretreatment (T0)

| Cephalometric parameters | MT                 | CA                 | $P$ value          |
|--------------------------|--------------------|--------------------|--------------------|
|                          | Mean $\pm$ SD      | Mean $\pm$ SD      |                    |
| FH-SN ( $^\circ$ )       | $8.55 \pm 3.23$    | $7.38 \pm 2.99$    | 0.289              |
| SNA ( $^\circ$ )         | $81.43 \pm 4.03$   | $85.17 \pm 5.22$   | 0.029*             |
| SNB ( $^\circ$ )         | $78.12 \pm 4.60$   | $82.38 \pm 4.71$   | 0.013*             |
| ANB ( $^\circ$ )         | $3.31 \pm 2.44$    | $2.79 \pm 1.73$    | 0.493              |
| Wits appraisal (mm)      | $-2.86 \pm 4.05$   | $-3.12 \pm 2.14$   | 0.827              |
| A-Nperp (mm)             | $-0.19 \pm 3.26$   | $-2.63 \pm 4.55$   | 0.078              |
| Pg-Nperp (mm)            | $-7.27 \pm 8.06$   | $-2.43 \pm 8.22$   | 0.095              |
| SN-MP ( $^\circ$ )       | $35.57 \pm 7.19$   | $33.08 \pm 5.74$   | 0.284              |
| OP-SN ( $^\circ$ )       | $19.67 \pm 4.63$   | $15.97 \pm 6.15$   | 0.054              |
| Y-axis ( $^\circ$ )      | $67.72 \pm 4.67$   | $68.14 \pm 4.21$   | 0.789              |
| U1-NA ( $^\circ$ )       | $25.05 \pm 8.54$   | $29.87 \pm 7.31$   | 0.093              |
| U1-NA (mm)               | $6.51 \pm 2.68$    | $7.28 \pm 2.73$    | 0.415              |
| L1-NB ( $^\circ$ )       | $38.25 \pm 8.47$   | $40.31 \pm 6.48$   | 0.443              |
| L1-NB (mm)               | $8.79 \pm 2.63$    | $8.97 \pm 2.20$    | 0.832              |
| L1-MP ( $^\circ$ )       | $97.69 \pm 8.96$   | $104.95 \pm 8.22$  | 0.021*             |
| U1-L1 ( $^\circ$ )       | $114.01 \pm 12.33$ | $106.80 \pm 10.56$ | 0.083              |
| U1-OP (mm)               | $-1.40 \pm 2.66$   | $-1.38 \pm 1.65$   | 0.984              |
| ADH (mm)                 | $27.65 \pm 1.97$   | $26.63 \pm 2.41$   | 0.181              |
| U6-PP (mm)               | $20.08 \pm 1.55$   | $19.27 \pm 2.23$   | 0.223              |
| L6-MPperp (mm)           | $28.46 \pm 3.62$   | $31.15 \pm 2.99$   | 0.028*             |
| Overjet (mm)             | $2.67 \pm 0.64$    | $2.78 \pm 0.53$    | 0.587              |
| Overbite (mm)            | $-1.93 \pm 0.68$   | $-1.85 \pm 0.90$   | 0.771              |
| Pg-VRP (mm)              | $51.11 \pm 10.17$  | $54.02 \pm 8.94$   | 0.389              |
| Me-HRP (mm)              | $106.27 \pm 6.52$  | $108.29 \pm 7.03$  | 0.391              |
| LAFH (mm)                | $66.00 \pm 3.83$   | $65.71 \pm 4.87$   | 0.852              |
| Gender, n (%)            |                    |                    |                    |
| Male                     | 2 (13.3)           | 7 (36.8)           | 0.123 <sup>a</sup> |
| Female                   | 13 (86.7)          | 12 (63.2)          |                    |

Independent  $t$ -test; <sup>a</sup>Chi-square test; \* $P$  value < 0.05

Pg-VRP, representing the anteroposterior position of the mandible, increased significantly in both groups, with values of  $3.69 \pm 0.12$  mm in the MT group and  $1.83 \pm 0.71$  mm in the CA group. The increase was significantly greater in the MT group than in the CA group, with a mean difference of 1.86 mm ( $P$  value  $< 0.001$ ).

Lower anterior facial height (LAFH) decreased significantly in both groups, with reductions of

$3.43 \pm 0.25$  mm in the MT group and  $1.61 \pm 0.25$  mm in the CA group. The decrease was greater in the MT group by 1.82 mm ( $P$  value  $< 0.001$ ).

The lower incisor position and inclination, including L1-NB angulation, L1-NB distance, and L1-MP, showed no significant changes in either group ( $P$  value  $> 0.05$ ).

**Table 2** Within-group comparisons of cephalometric parameters between pretreatment and 6 months of treatment (T0-T1)<sup>a</sup> and between-group comparisons of cephalometric parameter changes (MT vs CA)<sup>b</sup>.

| Cephalometric parameters | MT                  |                     |                        |                 | CA                  |                     |                        |                 | Mean Difference MT-CA | P value         |
|--------------------------|---------------------|---------------------|------------------------|-----------------|---------------------|---------------------|------------------------|-----------------|-----------------------|-----------------|
|                          | T0<br>Mean $\pm$ SD | T1<br>Mean $\pm$ SD | T1-T0<br>Mean $\pm$ SD | P value         | T0<br>Mean $\pm$ SD | T1<br>Mean $\pm$ SD | T1-T0<br>Mean $\pm$ SD | P value         |                       |                 |
| ANB (°)                  | 3.31 $\pm$ 2.44     | 1.93 $\pm$ 2.31     | -1.38 $\pm$ 0.64       | $< 0.001^{***}$ | 2.79 $\pm$ 1.73     | 2.67 $\pm$ 1.77     | -0.13 $\pm$ 0.35       | 0.127           | 1.25                  | $< 0.001^{***}$ |
| Wits appraisal           | -2.86 $\pm$ 4.05    | -5.12 $\pm$ 2.95    | -2.26 $\pm$ 1.87       | $< 0.001^{***}$ | -3.12 $\pm$ 2.14    | -3.58 $\pm$ 2.72    | -0.47 $\pm$ 1.82       | 0.276           | -1.79                 | 0.009**         |
| OP-SN (°)                | 19.67 $\pm$ 4.63    | 23.65 $\pm$ 4.63    | 3.98 $\pm$ 1.24        | $< 0.001^{***}$ | 15.97 $\pm$ 6.15    | 17.06 $\pm$ 6.17    | 1.09 $\pm$ 0.53        | $< 0.001^{***}$ | 2.89                  | $< 0.001^{***}$ |
| U1-NA (°)                | 25.05 $\pm$ 8.54    | 27.73 $\pm$ 7.67    | 2.67 $\pm$ 4.83        | 0.050           | 29.87 $\pm$ 7.31    | 23.99 $\pm$ 5.31    | -5.87 $\pm$ 3.60       | $< 0.001^{***}$ | 8.55                  | $< 0.001^{***}$ |
| U1-NA (mm)               | 6.51 $\pm$ 2.68     | 7.27 $\pm$ 2.61     | 0.76 $\pm$ 1.19        | 0.027*          | 7.28 $\pm$ 2.73     | 5.30 $\pm$ 1.97     | -1.98 $\pm$ 1.14       | $< 0.001^{***}$ | 2.74                  | $< 0.001^{***}$ |
| L1-NB (°)                | 38.25 $\pm$ 8.47    | 38.19 $\pm$ 8.52    | -0.06 $\pm$ 0.21       | 0.294           | 40.31 $\pm$ 6.48    | 40.18 $\pm$ 6.57    | -0.13 $\pm$ 0.22       | 0.024*          | 0.07                  | 0.385           |
| L1-NB (mm)               | 8.79 $\pm$ 2.63     | 8.78 $\pm$ 2.68     | -0.01 $\pm$ 0.25       | 0.921           | 8.97 $\pm$ 2.20     | 8.83 $\pm$ 2.19     | -0.14 $\pm$ 0.39       | 0.143           | 0.13                  | 0.249           |
| L1-MP (°)                | 97.69 $\pm$ 8.96    | 97.64 $\pm$ 8.85    | -0.05 $\pm$ 0.34       | 0.601           | 104.95 $\pm$ 8.22   | 104.97 $\pm$ 8.24   | 0.02 $\pm$ 0.19        | 0.721           | -0.06                 | 0.529           |
| U1-L1 (°)                | 114.01 $\pm$ 12.33  | 117.06 $\pm$ 10.72  | 3.05 $\pm$ 3.45        | 0.004**         | 106.80 $\pm$ 10.56  | 112.29 $\pm$ 10.49  | 5.49 $\pm$ 2.91        | $< 0.001^{***}$ | -2.44                 | 0.037*          |
| U1-OP (mm)               | -1.40 $\pm$ 2.66    | -0.09 $\pm$ 2.46    | 1.31 $\pm$ 0.51        | $< 0.001^{***}$ | -1.38 $\pm$ 1.65    | 0.62 $\pm$ 1.36     | 2.01 $\pm$ 0.43        | $< 0.001^{***}$ | -0.69                 | $< 0.001^{***}$ |
| ADH (mm)                 | 27.65 $\pm$ 1.97    | 27.87 $\pm$ 1.95    | 0.22 $\pm$ 0.72        | 0.258           | 26.63 $\pm$ 2.41    | 28.56 $\pm$ 2.43    | 1.93 $\pm$ 0.38        | $< 0.001^{***}$ | -1.71                 | $< 0.001^{***}$ |
| U6-PP (mm)               | 20.08 $\pm$ 1.55    | 18.07 $\pm$ 1.46    | -2.01 $\pm$ 0.22       | $< 0.001^{***}$ | 19.27 $\pm$ 2.23    | 18.45 $\pm$ 2.20    | -0.82 $\pm$ 0.12       | $< 0.001^{***}$ | -1.19                 | $< 0.001^{***}$ |
| Overjet (mm)             | 2.67 $\pm$ 0.64     | 2.49 $\pm$ 0.71     | -0.18 $\pm$ 0.56       | 0.234           | 2.78 $\pm$ 0.53     | 2.02 $\pm$ 0.38     | -0.76 $\pm$ 0.35       | $< 0.001^{***}$ | 0.58                  | 0.002**         |
| Overbite (mm)            | -1.93 $\pm$ 0.68    | 1.24 $\pm$ 0.68     | 3.17 $\pm$ 0.44        | $< 0.001^{***}$ | -1.85 $\pm$ 0.90    | 1.26 $\pm$ 0.65     | 3.11 $\pm$ 0.42        | $< 0.001^{***}$ | 0.14                  | 0.683           |
| Pg-VRP (mm)              | 51.11 $\pm$ 10.17   | 54.80 $\pm$ 10.15   | 3.69 $\pm$ 0.12        | $< 0.001^{***}$ | 54.02 $\pm$ 8.94    | 55.85 $\pm$ 9.09    | 1.83 $\pm$ 0.71        | $< 0.001^{***}$ | -1.86                 | $< 0.001^{***}$ |
| LAFH (mm)                | 66.00 $\pm$ 3.83    | 62.57 $\pm$ 3.96    | -3.43 $\pm$ 0.25       | $< 0.001^{***}$ | 65.71 $\pm$ 4.87    | 64.10 $\pm$ 4.95    | -1.61 $\pm$ 0.25       | $< 0.001^{***}$ | 1.82                  | $< 0.001^{***}$ |

<sup>a</sup>Paired *t*-test; <sup>b</sup>Independent *t*-test; \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ ,

## Discussion

Results showed no significant difference in open bite reduction between the two groups at 6 months. Open bite reductions were 3.17 mm in the MT group and 3.11 mm in the CA group. Previous studies have reported varying amounts of anterior open bite reduction through posterior teeth intrusion using skeletal anchorage, depending on the treatment protocol. Akbaydogan et al. reported 5.8 mm of open bite closure with 4.01 mm of molar intrusion,<sup>16</sup> whereas Kim et al. reported 4.5 mm of open bite closure with 2.2 mm of molar intrusion.<sup>13</sup>

In the present study, the MT group showed greater molar intrusion, whereas the CA group relied more on maxillary incisor extrusion with limited posterior intrusion. This finding is consistent with previous reports showing relatively small amounts of molar intrusion with clear aligners, approximately 0.3–0.6 mm.<sup>19</sup> Therefore, incisor extrusion appeared to contribute more substantially to open bite correction in the CA group. These findings support the concept that clear aligners primarily correct anterior open bite through anterior extrusion rather than predictable molar intrusion.<sup>26</sup> In contrast, molar intrusion mechanics have demonstrated more pronounced posterior intrusion and associated mandibular autorotation, supporting the findings observed in the MT group.<sup>13,16</sup>

The cephalometric findings indicated improvements in overbite and overjet in both groups. In the MT group, overbite improvement was associated with a significant decrease in U6–PP. In the CA group, extrusion and retroclination of the maxillary incisors occurred to a greater extent than in the MT group. Decreases in U1-NA angulation and U1-NA distance were observed accompanied by extrusion of the maxillary incisor relative to the functional occlusal plane (U1-OP) and an increase in anterior dental height (ADH). These vertical and anteroposterior changes may be attributed to the extrusion and palatal crown tipping of the maxillary incisors during

clear aligner treatment. In contrast, in the MT group, alignment of the anterior teeth to prevent interference may have contributed to an increase in U1-NA angulation, whereas no significant vertical changes in the maxillary incisors were observed.

## Factors contributing to anterior open bite correction in MT and CA

ANCOVA indicated that age differences between the groups did not affect the primary outcome. Moreover, the study duration was only 6 months. In the MT group, treatment was limited to maxillary molar intrusion, and no appliances were placed in the mandibular arch that could have influenced vertical dentoalveolar changes. Similarly, in the CA group, treatment protocols did not include mechanics aimed at altering mandibular vertical position during the observation period. No significant vertical changes were observed in the mandibular incisors in either group. Therefore, the correction of anterior open bite was primarily attributed to maxillary dentoalveolar changes, specifically maxillary incisor extrusion and maxillary molar intrusion.

Anterior dental height (ADH) was used to represent the vertical position of the maxillary incisors, whereas the vertical position of the maxillary molars was assessed using U6–PP. In the MT group, no significant change in ADH was observed. The use of a partial fixed appliance in the maxillary anterior segment may have acted as a confounding factor when interpreting changes in maxillary incisor position; therefore, the overbite change in the MT group cannot be attributed solely to molar intrusion. However, the absence of a significant change in ADH suggests that true maxillary incisor extrusion was minimal, supporting the interpretation that molar intrusion was the major contributor to overbite correction in the MT group.

In the MT group, the increase in overbite was primarily attributed to maxillary molar intrusion, which measured 2.01 mm and accounted for 93.06 % of the total overbite increase (3.17 mm), whereas incisor

extrusion of 0.22 mm contributed only 6.94 %. In the CA group, maxillary molar intrusion was 0.82 mm, accounting for 38 % of the overbite increase, whereas ADH increased by 1.93 mm, accounting for 62 % of overbite correction. A previous study reported that only 15 % of overbite correction was attributed to molar intrusion with clear aligners.<sup>23</sup> The difference in the percentage of molar intrusion may be related to variations in treatment protocols, including aligner thickness and material properties, which influence the bite-block effect. That study reported approximately 1 mm of unplanned molar intrusion with a 0.75-mm-thick clear aligner.<sup>23</sup> In the present study, the aligner thickness was 1 mm, and squeezing exercises were prescribed; therefore, the observed 0.82 mm of molar intrusion may be partly explained by these factors. Previous studies have shown that squeezing with clear aligners increases bite force in anterior open bite patients.<sup>25</sup> This increased force may have contributed to the amount of molar intrusion achieved. In addition, patient compliance with aligner wear and squeezing exercises may further influence the magnitude of intrusion.

### Differences in magnitude and duration of force between MT and CA

In the MT group, the TPA helped prevent palatal crown tipping of the maxillary first molars, while sectional 0.017 × 0.025-inch stainless steel wires were placed bilaterally on the maxillary posterior teeth to consolidate the posterior segments. The vertical intrusive forces were controlled, and a light continuous force (150 grams/side, 37.5 grams/tooth) was applied for 6 months. In the CA group, the anterior teeth were programmed for extrusion, and patients were instructed to regularly clench on the clear aligner to promote posterior teeth intrusion. The occlusal force generated on the posterior teeth during squeezing exercises ranged from approximately 195.23–342.98 Newtons.<sup>25</sup> In addition, the force delivered by the aligner ranged from

0.18–2.91 Newtons (10.20–203.94 grams), depending on material properties, thermoplastic sheet thickness, amount of activation, and biomechanics.<sup>27</sup> However, in the CA group, the magnitude and duration of the intrusive force could not be directly measured. Moreover, the force generated by the clear aligner is intermittent and highly dependent on patient compliance with consistent aligner wear to achieve effective anterior open bite correction.

### Differences in force systems and their effects to molars and incisors

In the MT group, the posterior segment was consolidated and intruded as a unit. The line of force passed through the CRe of the posterior segment to minimize occlusal plane tipping (Figures 4a, 4b). In the CA group, the occlusal force contributing to posterior

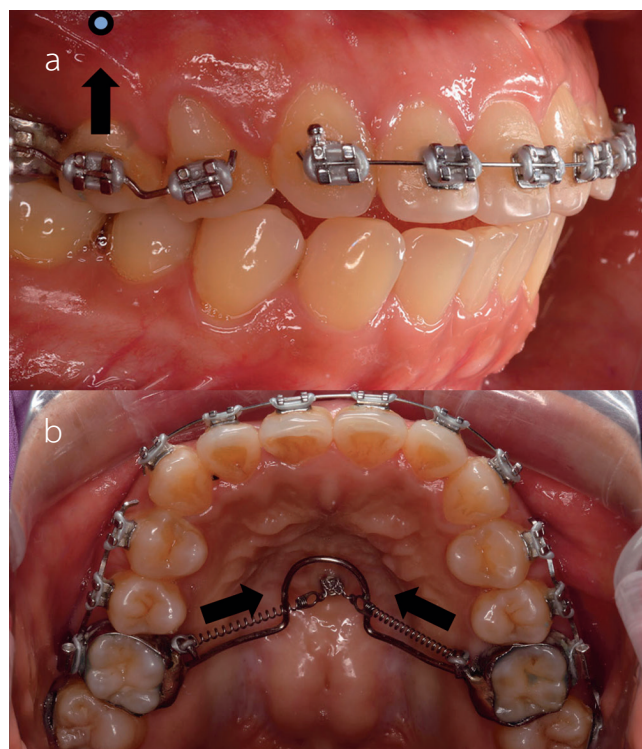


**Figure 4** Schematic representation of dentoalveolar changes produced by miniscrew-assisted transpalatal arch mechanics. (a) Maxillary posterior intrusion in the vertical dimension. (b) In the transverse dimension, the TPA prevents posterior teeth from palatal tipping.

teeth intrusion depended on the factors mentioned above. Based on the study by Suh et al., the primary mechanics for correcting anterior open bite with clear aligner is the anterior teeth extrusion. Therefore, beveled attachments were designed on the maxillary incisors to facilitate controlled extrusion of the maxillary anterior teeth. Molar intrusion in clear aligner therapy is mainly influenced by the full-coverage design of the aligner and force distribution across the posterior segment, rather than by attachments on the molars. Thus, attachments were not placed on the maxillary first molars.

The results showed intrusion of the maxillary first molars. It was hypothesized that this intrusion may have occurred as a result of occlusal forces generated by the bite-block effect of clear aligners. This effect occurs when the posterior teeth are separated by the thickness of the aligner, which acts as a posterior bite block and may contribute to posterior teeth intrusion, open bite closure, and vertical control during treatment. When the aligner was fully seated, vertical force was applied primarily to the inclined surfaces of the attachments on the maxillary incisors. As the line of force passed anterior to the CRe (Figure 5), it likely contributed to both extrusion and palatal tipping of the incisors. Consistent with the CA mechanics, U1-NA angulation and distance in the CA group decreased significantly by 5.87° and 1.98 mm, respectively. Furthermore, the reductions in overjet, together with increases in overbite, interincisal angle, and ADH in the CA group, indicate extrusion and retroclination of the maxillary incisors, which contributed to anterior open bite correction (Figures 6a–d). Although clear aligners may result in incisor extrusion, the amount of extrusion was clinically controlled through the treatment protocol and participant selection criteria. Therefore, the inclusion of these participants was not expected to result in excessive incisor display.

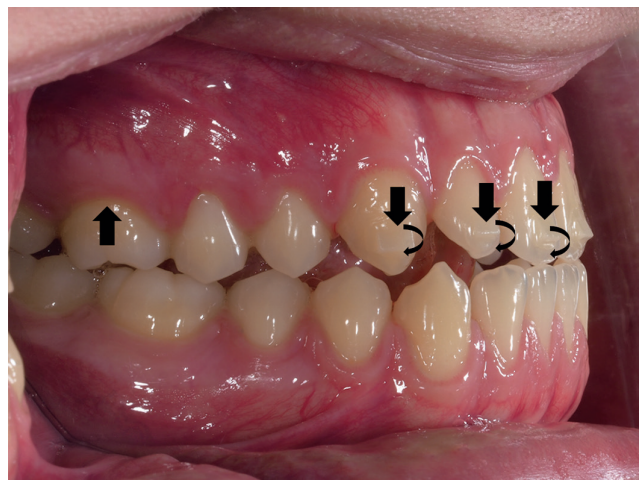


**Figure 5** Schematic representation of dentoalveolar changes produced by clear aligners in anterior open bite correction. The extrusive force acting on the maxillary anterior teeth passes anterior to the CRe, generating a moment that may contribute to palatal tipping of the anterior teeth.

### Occlusal plane changes

The OP-SN angle increased to a greater extent in the MT group than in the CA group, likely due to the greater amount of maxillary molar intrusion in the MT group, which directly influenced the orientation of the functional occlusal plane. Changes in U1-OP indicated a tendency toward maxillary incisor extrusion relative to the functional occlusal plane in both groups. In the CA group, this change was primarily attributable to extrusion of the maxillary incisors. In contrast, in the MT group, the changes in U1-OP were mainly related to posterior teeth intrusion accompanied by alterations in the functional occlusal plane. In addition, ADH showed no significant change in the MT group, further supporting the interpretation that true maxillary incisor extrusion was minimal, as discussed above.

### Vertical control during and after treatment

Previous studies have reported an increase in bite force while wearing an acrylic splint or clear aligner, as these materials provide a more comfortable surface for biting than direct occlusal contact.<sup>28,30</sup>

Squeezing exercises may further increase muscle activity and enhance bite force on the posterior teeth.<sup>25</sup> Increasing both the magnitude and duration of intrusive forces generated during occlusal contact while wearing a clear aligner may help control the vertical dimension.<sup>28</sup> In the present study, maxillary first molar intrusion was observed in the CA group, which may be partly attributed to the occlusal forces generated during aligner wear. Therefore, performing squeezing exercises while wearing clear aligners that cover all occlusal surfaces, as well as during the retention period, may contribute to posterior teeth intrusion and enhanced post-treatment stability.

### Clinical relevance

In the MT group, maxillary molar intrusion was the major contributor to overbite increase, accounting for 93.06 % of the overbite increase, whereas maxillary incisor extrusion contributed only 6.94 %. In contrast, in the CA group, maxillary molar intrusion accounted for 38 % of overbite increase, whereas the extrusion of the maxillary incisors contributed 62 %. Within this initial phase, both treatment modalities demonstrated measurable vertical and sagittal changes. The decrease in ANB angle and increase in Pg-VRP indicate counterclockwise rotation of the mandible. Moreover, a decrease in lower anterior facial height was observed in both groups. These vertical and sagittal changes were more pronounced in the MT group.

This study demonstrates the early effects of anterior open bite correction using two different appliance mechanics. Maxillary molar intrusion was mainly observed in the MT group, whereas maxillary incisor changes were more pronounced in the CA group. Based on these initial findings, MT mechanics may be considered for patients with mild to moderate skeletal Class II anterior open bite with a hyperdivergent pattern. Posterior teeth intrusion followed by counterclockwise mandibular rotation may contribute to improvements in skeletal Class II discrepancy and vertical facial dimension. Conversely,

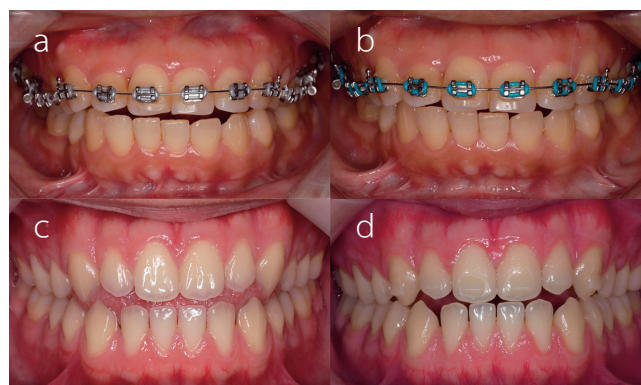


**Figure 6** Intraoral photographs. (a) Pretreatment conditions in the MT group. (b) After 6 months of intrusion in the MT group. (c) Pretreatment conditions in the CA group. (d) After 6 months of treatment in the CA group.

in patients with a Class III open bite or hypodivergent pattern, MT mechanics should be used with caution, as they may adversely affect the facial profile and decrease lower facial height, which may be detrimental to facial esthetics. CA mechanics—the extrusion and retroclination of maxillary incisors—may be suitable for anterior open bite patients with a low smile line and mild incisor protrusion or proclination. These dentoalveolar changes may contribute to improvements in the smile line and in the inclination and position of maxillary incisors.

Addressing the etiology of anterior open bite, including parafunctional habits such as tongue thrusting, is essential for posttreatment stability, particularly in clear aligner treatment, in which maxillary incisors were primarily extruded and retroclined. Persistent tongue pressure may contribute to relapse of the maxillary incisors if such habits are not eliminated. In addition, posttreatment vertical control through squeezing exercises is recommended to reduce the risk of posterior teeth relapse.

Although statistically significant differences were observed between the MT and CA groups for certain variables, the clinical relevance of these differences should be interpreted with caution. For some parameters, the magnitude of between-group

differences was relatively small and may not translate into substantial clinical advantages. Therefore, these findings indicate early differences in dentoalveolar and skeletal responses rather than definitive superiority of one treatment modality over the other.

### Limitations of the study

This study has several limitations. First, the 6-month follow-up period was insufficient to evaluate the long-term effects of treatment. Second, the study could not clearly differentiate between dental and skeletal contributions to open bite correction. Third, the biomechanical interpretations were based on theoretical considerations rather than direct force measurements. In addition, potential confounding factors such as patient compliance may have influenced the results. Therefore, further long-term, prospective studies are needed to validate these findings.

### Further study

Further studies should evaluate the skeletal and soft tissue effects of these two mechanics in anterior open bite correction. Long-term outcomes and stability also require investigation. In addition, the magnitude and duration of forces generated during clear aligner treatment should be evaluated to better understand the underlying biomechanics.

## Conclusion

1. Miniscrew-assisted transpalatal arch mainly intruded maxillary posterior teeth with minimal incisor changes.
2. Clear aligner treatment primarily resulted in maxillary incisor extrusion and retroclination, with limited posterior teeth intrusion.
3. Based on these initial findings, miniscrew-assisted transpalatal arch mechanics may be considered for patients with mild to moderate skeletal Class II anterior open bite with a hyperdivergent pattern, whereas clear aligner mechanics may be more suitable for patients with a low smile line and mild incisor protrusion or proclination.

## Author contributions

**Suthinun Suksutthiphan:** Conceptualization, Investigation, Formal analysis, Writing – original draft, Writing – review & editing; **Angkana Thearnmontree:** Formal analysis, Writing – review & editing; **Chidchanok Leethanakul:** Conceptualization, Supervision, Project administration, Resources, Funding acquisition, Writing – review & editing.

## Ethical statement

This study was approved by the Human Ethics Committee of the Faculty of Dentistry, Prince of Songkla University (Ethical approval number: EC6503-013).

## Disclosure statement

The authors have no conflicts of interest.

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None.

## AI-assisted writing declaration

The authors used ChatGPT (OpenAI, GPT-5.5) solely for language editing and manuscript refinement. All scientific content was developed and verified by the authors, who take full responsibility for the accuracy and integrity of the manuscript.

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## References

- Ngan P, Fields HW. Open bite: a review of etiology and management. *Pediatr Dent* 1997;19(2):91-8.
- Lin LH, Huang GW, Chen CS. Etiology and treatment modalities of anterior open bite malocclusion. *J Exp Clin Med* 2013;5(1):1-4.
- Subtelny JD, Sakuda M. Open-bite: diagnosis and treatment. *Am J Orthod* 1964;50(5):337-58.
- Turvey TA, Journot V, Epker BN. Correction of anterior open bite deformity: a study of tongue function, speech changes, and stability. *J Maxillofac Surg* 1976;4(2):93-101.
- Mizrahi E. A review of anterior open bite. *Br J Orthod* 1978;5(1):21-7.
- Ng CS, Wong WK, Hägg U. Orthodontic treatment of anterior open bite. *Int J Paediatr Dent* 2008;18(2):78-83.
- McSherry PF. Aetiology and treatment of anterior open bite. *J Ir Dent Assoc* 1996;42(2):20-6.
- Fränkel R, Fränkel C. A functional approach to treatment of skeletal open bite. *Am J Orthod* 1983;84(1):54-68.
- Kim YH. Anterior open bite and its treatment with multiloop edgewise archwire. *Angle Orthod* 1987;57(4):290-321.
- Kuster R, Ingervall B. The effect of treatment of skeletal open bite with two types of bite-blocks. *Eur J Orthod* 1992;14(6):489-99.
- Erbay E, Uğur T, Ülgen M. The effects of Frankel's function regulator (FR-4) therapy on Angle Class I skeletal anterior open bite malocclusion. *Am J Orthod Dentofacial Orthop* 1995;108(1):9-21.
- Hsu JY, Cheng JH, Feng SW, Lai PC, Yoshida N, Chiang PC. Strategic treatment planning for anterior open bite: a comprehensive approach. *J Dent Sci* 2024;19(3):1328-37.
- Kim K, Choy K, Park YC, Han SY, Jung H, Choi YJ. Prediction of mandibular movement and its center of rotation for nonsurgical correction of anterior open bite via maxillary molar intrusion. *Angle Orthod* 2018;88(5):538-44.
- Sherwood KH, Burch JG, Thompson WJ. Closing anterior open bites by intruding molars with titanium miniplate anchorage. *Am J Orthod Dentofacial Orthop* 2002;122(6):593-600.
- Tasanapanont J, Wattanachai T, Apisariyakul J, Pothacharoen P, Ongchai S, Kongtawelert P, et al. Biochemical and clinical assessments of segmental maxillary posterior tooth intrusion. *Int J Dent* 2017;2017:2689642.
- Akbaydogan LC, Akin M. Cephalometric evaluation of intrusion of maxillary posterior teeth by miniscrews in the treatment of open bite. *Am J Orthod Dentofacial Orthop* 2022;161(5):621-7.
- Felicita AS, Wahab TU. Intrusion of the maxillary posterior teeth with a single buccal mini-implant positioned bilaterally in young adults with a tendency toward hyperdivergence: a clinical study. *J Orthod* 2022;49(3):338-46.
- Ogura H, Numazaki K, Oyanagi T, Seiryu M, Ito A, Noguchi T, et al. Three-dimensional evaluation of treatment effects and post-treatment stability of maxillary molar intrusion using temporary anchorage devices in open bite malocclusion. *J Clin Med* 2024;13(10):2753.
- Suh H, Garnett BS, Mahood K, Mahjoub N, Boyd RL, Oh H. Treatment of anterior open bites using non-extraction clear aligner therapy in adult patients. *Korean J Orthod* 2022;52(3):210-9.
- Moshiri S, Araújo EA, McCray JF, Thiesen G, Kim KB. Cephalometric evaluation of adult anterior open bite non-extraction treatment with Invisalign. *Dent Press J Orthod* 2017;22(5):30-8.
- Talens-Cogollos L, Vela-Hernández A, Peiró-Guijarro MA, García-Sanz V, Montiel-Company JM, Gandía-Franco JL, et al. Unplanned molar intrusion after Invisalign treatment. *Am J Orthod Dentofacial Orthop* 2022;162(4):451-8.
- Steele BP, Pandis N, Darendeliler MA, Papadopoulos AK. Dentoskeletal effects of clear aligners vs miniplate-supported posterior intrusion in adult anterior open bite: a multicenter retrospective cohort study. *Am J Orthod Dentofacial Orthop* 2022;162(2):214-28.
- Suh H, Garnett BS, Mahood K, Oh H. Anterior open bite treatment with clear aligners in adults. *Semin Orthod* 2026;32(1):231-43.
- Withayanukonkij W, Chanmanee P, Promsawat M, Viteporn S, Leethanakul C. Root resorption during maxillary molar intrusion with clear aligners: a randomized controlled trial. *Angle Orthod* 2023;93(6):629-37.
- Withayanukonkij W, Leethanakul C, Tangpothitham S. The change of occlusal bite force during clear aligner treatment and squeezing exercise. *Thai J Orthod* 2024;14(1):21-30.
- Charoenrat T, Uengkajornkul P, Changsiripun C. Incisor extrusion with or without molar intrusion for the correction of anterior open bite with clear aligners and comparison of outcomes with fixed appliances incorporating temporary anchorage devices: a systematic review and meta-analysis. *Korean J Orthod* 2026;56(1):69-86.
- Kohda N, Iijima M, Muguruma T, Brantley WA, Ahluwalia KS, Mizoguchi I. Effects of mechanical properties of thermoplastic materials on the initial force of thermoplastic appliances. *Angle Orthod* 2013;83(3):476-83.
- Serra CM, Manns AE. Bite force measurements with hard and soft bite surfaces. *J Oral Rehabil* 2013;40(8):563-8.
- Tortopidis D, Lyons MF, Baxendale RH, Gilmour WH. The variability of bite force measurement between sessions in different positions within the dental arch. *J Oral Rehabil* 1998;25(9):681-6.
- Yamaguchi K. Etiological and therapeutic considerations with open bite. In: Nanda R, editor. *Current therapy in orthodontics*. St. Louis (Mo): Mosby; 2010. p.159-70.