Short-term stability of anterior open bite treatment with clear aligners in adults

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Introduction: This study aimed to examine the stability of anterior open bite (AOB) treatment with clear aligners. **Methods:** This retrospective cohort study included 52 adult AOB patients (aged >18 years; 15 males, 37 females) who underwent nonextraction clear aligner treatment and were at least 1 year posttreatment. Eleven cephalometric measurements were evaluated at pretreatment, end of active treatment, and at least 1-year posttreatment. Overbite change, the primary outcome variable, and other cephalometric changes during treatment and retention were calculated, and repeated measures analysis of variance were performed. Stepwise multiple regression was used to make a prediction equation for open bite relapse. **Results:** The mean retention period was 2.1 ± 1.1 years. The mean change in overbite during treatment was 3.3 ± 1.5 mm; 6% of patients presented relapse at least 1 year after treatment completion. The mean change of overbite (0.2 ± 0.5 mm) during the retention period was not statistically significant ($P = 0.59$). None of the 11 cephalometric measurements showed significant change during the retention period. The prediction model showed that only the coefficient for a tongue posture issue at the initial examination was statistically significant. **Conclusions:** AOB was successfully corrected in all 52 patients using only clear aligners with no additional adjunctive aids such as microimplants. When retained with maxillary and mandibular fixed retainers and maxillary and mandibular vacuum-formed retainers, there was no significant change in cephalometric measurements during the short-term retention period. (Am J Orthod Dentofacial Orthop 2023;164:774-82)

Anterior open bites (AOB) are challenging malocclusions to correct and retain. Although most patients are successfully treated, maintaining positive overbite after treatment can be difficult.[1] Etiologic factors that can persist after treatment and contribute to AOB relapse include tongue posture and size, digit-sucking habits, respiratory problems, condylar resorption, and unfavorable growth patterns.[2-4] Relapse can also be attributed to surgical instability or using less stable types of tooth movement, such as extruding anterior teeth.[5] However, there are no characteristics that are clear predictors of relapse.[2]

Few studies have been published on the stability of AOB treatment in adults. A meta-analysis published in 2011 revealed no high-level controlled evidence for the stability of AOB treatment.[6] Previous studies reported different rates of open bite relapse because various age groups and treatment modalities were included.[5-8] Unlike nongrowing adults, vertical growth and dental eruption can affect the relapse rate in growing patients. In addition, different treatment modalities can result in different relapse rates.

There is no consensus for the most desirable AOB treatment modality, whether extrusion of anterior teeth, intrusion of posterior teeth, extractions, and/or orthognathic surgery. The National Dental Practice-Based Research Network Adult Anterior Open Bite Study revealed 57%-83% stability of AOB correction in adult patients, depending on treatment and retainer modalities.[5] To further promote stability, myofunctional therapy or behavior-modifying appliances may also be indicated to correct inadequate tongue posture or digit-sucking habits.[6]

Clear aligners may present an advantage in controlling the vertical dimension compared with extrusive mechanics used in fixed appliance therapy.[9-13] A previous study showed that <1 mm of molar intrusion was achievable with clear aligners.[12] In contrast, another study reported that the Invisalign appliance corrected mild-to-moderate AOB mainly through incisor extrusion.[14]

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However, the stability of AOB correction using clear aligners has not been investigated with sufficient sample sizes. The study aimed to report on the outcome and stability of nonextraction AOB treatment with clear aligners and to investigate factors that might influence stability in adults. The following 2 null hypotheses were tested: (1) there is no difference between overbite after treatment and overbite after at least 1 year of retention, and (2) there is no linear relationship between predictor variables and AOB relapse.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board at the University of the Pacific. This study was a retrospective cohort study with a prospective aspect. Patients who completed treatment were evaluated retrospectively. Prospectively, patients were recalled for retention records. Participants were offered new retainers as compensation.

Sample size calculations were conducted. A sample size of 34 subjects was estimated using an effect size of 0.5 at a power of 80% and a significance level of 0.05. A previous study had reported a standard deviation of 1 for overbite change during retention.[15] To detect significant differences of 0.5 mm, an effect size of 0.5 was chosen.

The sample was drawn from the database of patients treated at the practice of a single board-certified (American Board of Orthodontics) clinician (B.S.G.) who is also a top 1% Invisalign provider. The clinician was not involved in the sampling process to minimize selection bias. A list of all patients who started and completed clear aligner treatment between January 2011 and April 2021 was obtained. The primary inclusion criteria were (1) receipt of clear aligner treatment; (2) aged >18 years at the beginning of treatment; (3) overbite less than −0.5 mm in lateral cephalogram tracing at pretreatment; and (4) complete records including lateral cephalograms and study casts, at pretreatment (T1), end of active treatment (T2), and at least 1-year posttreatment (T3).

All eligible patients were included regardless of the initial complexity of malocclusion, the number of aligners used, or the number of refinements. Patients with craniofacial anomalies, fixed orthodontic treatment, limited treatment, teeth extraction other than third molars, and surgeries to close open bites were excluded. To identify patients with AOB, 2 research dentists visually examined initial 2-dimensional conventional lateral cephalograms and photographs of all eligible adult patients using Dolphin Imaging software (version 11.8; Dolphin Imaging and Management Solutions, Chatsworth, Calif). The AOB was defined as less than −0.5 mm overbite in the T1 cephalometric tracing. The overbite was recorded by measuring the distance between the incisal edges of the maxillary and mandibular central incisors perpendicular to the functional occlusal plane. Among 177 adult patients with AOB who completed treatment by April 2021, 52 agreed to take retention records that included lateral cephalograms. Therefore, the final sample comprised 52 adult patients with complete records of at least 1-year posttreatment (Fig 1). One examiner (H.S.) reviewed chart notes, including previous orthodontic treatment history and tongue thrust or posture issues.

Myofunctional therapy was discussed when tongue thrust or inadequate tongue position was identified before treatment. Third molar extractions were recommended if they occluded with the opposing teeth. All the patients presented with mild-to-moderate crowding, resolved by interproximal reduction and arch expansion. When planning treatment, the clinician focused on maxillary and mandibular molar intrusion to level the curve of Spee. For patients requiring more incisal display, anterior extrusion was also planned to help level the curve of Spee. Mandibular incisor retraction was planned to help correct Class III malocclusions, whereas maxillary incisor retraction was planned to help decrease overjet in patients with Class II malocclusion. The patients were instructed to change their aligners every 7-10 days. Treatment did not incorporate any temporary skeletal anchorage devices. The clinician's retention protocol was maxillary and mandibular bonded retainers and nighttime maxillary and mandibular overlay vacuum-formed retainer wear.

T1, T2, and T3 lateral cephalograms were imported into Dolphin Imaging software. One examiner (H.S.) performed cephalometric landmark location and superimpositions using Dolphin Imaging software. Following the anterior cranial base, maxillary, and mandibular structural superimpositions, 3 reference planes (S-N, ANS-PNS, and Go-Me) were transferred from the T1 to the T2 tracing. Eleven cephalometric measurements were generated by Dolphin Imaging software (Fig 2). Three months later, the same examiner randomly selected 20 cephalometric radiographs and performed the tracings and measurements again to calculate the intraclass correlation coefficient and the Dahlberg measurement error to assess reproducibility and reliability.

Statistical analysis

Descriptive statistics, including mean, standard deviation, range, and percentage, were calculated. Positive overbite in the cephalometric tracing at T2 was a

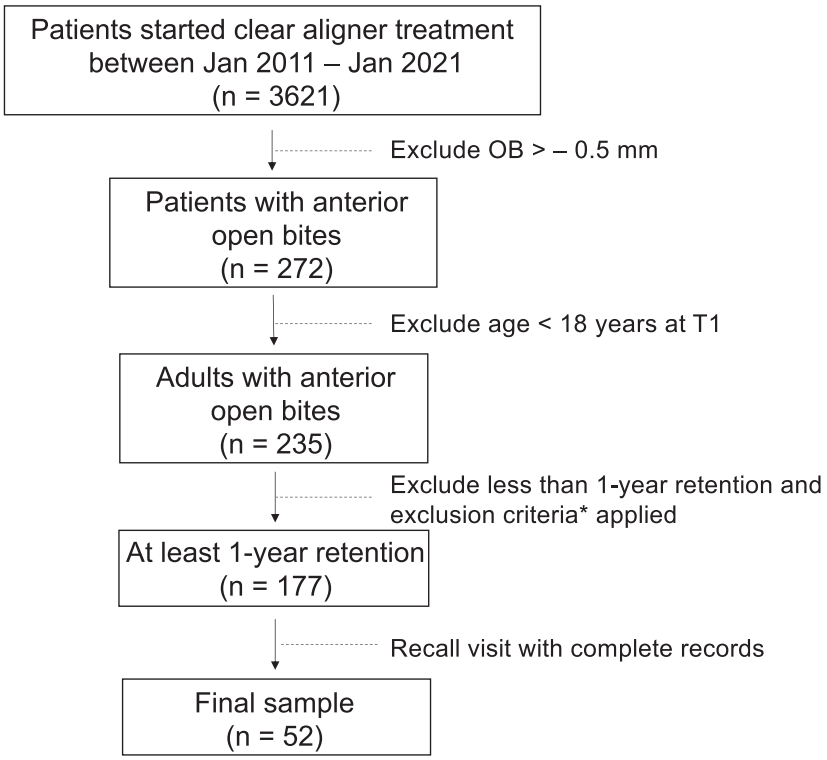

Fig 1. Sample flow chart. *OB,* overbite. *Craniofacial anomalies, limited treatment, surgical treatment, extraction other than third molars.

successful open bite treatment result. Relapse was defined as negative overbite at T3. The relapse rate was calculated as the percentage of patients who presented relapse at T3. Stability was the percentage of patients with positive overbite in the cephalometric tracing at T3. Repeated measures analysis of variance and Tukey post-hoc test across T1, T2, and T3 measurements were performed. Stepwise multiple regression was used to make a prediction equation for open bite relapse. $P < 0.05$ were considered statistically significant. All statistical analyses were performed using SPSS (version 24.0; IBM, Armonk, NY) and language R (version 3.6.1; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The intraexaminer error was excellent. ICC was >0.98 for all the measurements. Dahlberg values were <1 mm or 1°, except for U1-SN at 1.4°. Table I shows sample characteristics; 71% of patients were female, and 79% were adults aged <40 years.

Overall, the mean age at T1 was 35.1 ± 11.6 years, the mean treatment duration was 1.5 ± 0.7 years, and the mean retention period was 2.1 ± 1.1 years ranging from 1 year to 5.2 years. Thirty-one patients had tongue position issues identified at the initial examination with or without temporomandibular joint problems. All the patients had maxillary and mandibular bonded retainers. Seven patients had bonded retainers removed >1 year after completion of treatment, whereas 1 patient had them removed 10 months after completion of treatment. Seven patients had a history of previous orthodontic treatment. Overlay vacuum-formed retainers were delivered to all patients for nighttime wear. The distribution of AOB severity is shown in Table I, representing about 42% of the sample who presented with >2 mm open bite. At T1, the mean overbite was −2.2 ± 1.5 mm, ranging from −5.6 to −0.5 mm, and the mean mandibular plane angle (MPA) was 39.6° ± 7.3 (Table II). At T2, positive overbite was achieved for all patients at a mean of 1.1 ± 0.7 mm. The mean change in overbite was 3.3 ± 1.5 mm, ranging from 1.4 to 8.5 mm (Table II). At T3, positive overbite was maintained in 94% of patients. Three of the 52 patients presented with negative overbites of −0.1, −0.4, and −1.2 mm at T3.

Cephalometric changes during treatment (T2 − T1) showed statistically significant changes in the vertical dimension: the magnitude of maxillary molar intrusion was small at 0.6 mm, but it was statistically significant

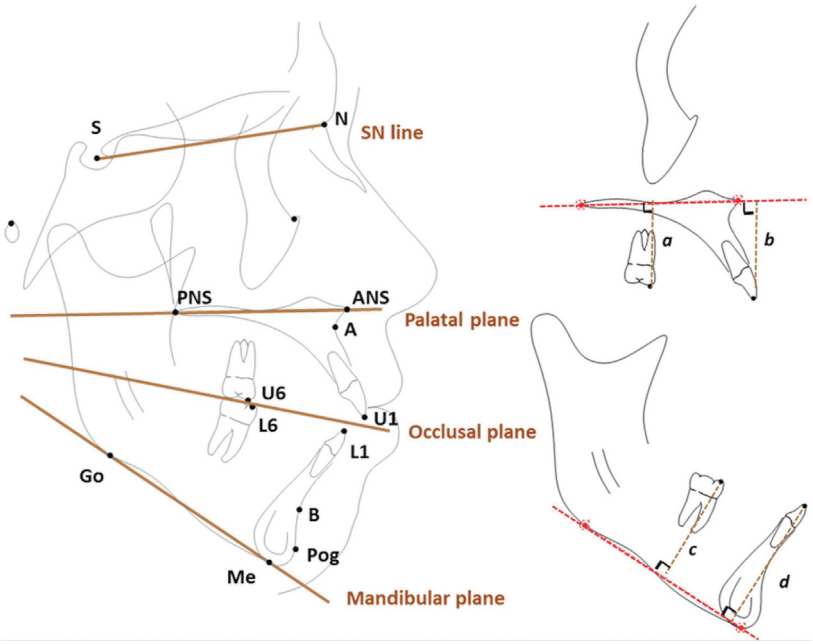

Fig 2. Cephalometric landmarks, reference planes, and measurements used in this study. Measurements were based on the same reference planes at T1, T2, and T3 tracings. *a* (U6-PP), perpendicular distance between mesiobuccal cusp of maxillary first molar and palatal plane (ANS-PNS) (mm); *b* (U1-PP), perpendicular distance between incisal edge of maxillary central incisor and palatal plane (mm); *c* (L6-MP), perpendicular distance between mesiobuccal cusp of mandibular first molar and mandibular plane (Go-Me) (mm); *d* (L1-MP), perpendicular distance between incisal edge of mandibular central incisor and mandibular plane (mm). *S*, sella; *N*, nasion; *A*, A point; *B*, B point; *Pog*, pogonion; *Go*, gonion; *Me*, menton; *ANS*, anterior nasal spine; *PNS*, posterior nasal spine.

($P < 0.0001$). Thirty-three percent of patients had ≥1 mm maxillary molar intrusion. One patient showed >2 mm maxillary molar intrusion. Maxillary molar intrusion contributed to the autorotation of the mandible and the reduction of the lower face height (Table II). MPA decreased by >1° in 37% and >2° in 8% of patients. Maxillary and mandibular incisors showed about 5° of retroclination (−5.2 and −4.0, respectively) and about 1 mm of extrusion (Table II). All the measurements, except for the overjet and mandibular molar vertical position, showed statistically significant changes during treatment.

For the first hypothesis, overbite change was not statistically significant during retention. The mean change in overbite during retention was 0.2 ± 0.5 mm (Table III, Fig 3, *A*). MPA showed a clinically small but statistically significant change (−0.55° ± 0.90°) during treatment; there was no significant change (0.12° ± 0.44°) during retention (Fig 3, *B*). Maxillary molar intrusion and incisor extrusion were statistically significant during treatment. However, during retention, there were no significant changes (Figs 3, *C-E*). No measurements showed statistically significant changes during retention, indicating good stability (Table III).

Although the mean overbite change during retention was insignificant, it showed large variability ranging from −1.5 to 1.0 mm. Therefore, stepwise multiple regression analysis was used to build an equation to predict overbite change during retention. Initial overbite, initial MPA, amount of incisor extrusion during treatment, incisor inclination changes during treatment, retention time, tongue position and habit, history of previous orthodontic treatment, and removal of fixed retainers were used as independent variables. Overbite change during retention was used as a dependent variable. The prediction model showed that only the coefficient for a tongue posture issue at the initial examination was statistically significant (Table IV). Initial overbite, initial MPA, amount of incisor extrusion during treatment, incisor inclination changes during treatment, retention time, history orthodontic treatment, and removal of fixed retainers did not show any statistically significant correlations with overbite change during retention (Tables IV and V). Therefore, with respect to the second hypothesis, no linear relationship was found between any predictor variables and AOB relapse, except for the presence of a tongue posture

Table I. Sample characteristics for patients with AOB

Category	*n (%)*
Sex	
Male	15 (28.8)
Female	37 (71.2)
Age (y)	
18-30	18 (34.6)
30-40	23 (44.2)
≥40	11 (21.2)
Initial open bite (mm)	
0.5-1.0	9 (17.3)
1-2	21 (40.4)
2-3	6 (11.5)
3-4	7 (13.5)
4-5	6 (11.5)
≥5	3 (5.8)
Angle classification	
Class I	30 (57.7)
Class II	14 (26.9)
Class III	8 (15.4)
History orthodontic treatment	
Yes[†]	7 (13.5)
No	45 (86.5)
Tongue thrust or posture issues identified	
Yes	31 (59.6)
No	21 (40.4)
Fixed retainers removed	
Yes	8 (15.4)
No	44 (84.6)
Retention (y)	
<2	30 (57.7)
2-3	13 (25.0)
3-5	9 (17.3)

[†]Three out of 7 patients received 4 premolar extraction treatments.

issue. The relationship between overbite changes during retention and the presence of a tongue posture issue is presented below.

$$Decrease\ in\ Overbite\ (mm) = 0.3\ (presence\ of\ tongue\ posture\ issue) - 0.35$$

$$(P = 0.02, R^2 = 0.09)$$

Although r^2 was only 0.09, explaining 9% of the variance, the independent t test revealed a statistically significant difference in overbite change during retention between the 2 groups (Fig 4). According to the regression model, if a patient presented with tongue posture problems at the initial examination, open bite relapse was >0.3 mm than in the absence of a tongue posture problem.

DISCUSSION

AOB correction was successful for all patients. Based on the changes during treatment, open bite closure with clear aligners was achieved by maxillary and mandibular incisor retroclination and extrusion, along with slight maxillary molar intrusion that accompanied mandibular counterclockwise rotation. The anterior extrusive and posterior intrusive forces are reciprocal and synergize to close the AOB.[16] A previous study suggested a moderate amount of presurgical incisor extrusion could be stable.[17] However, in most patients with hyperdivergent AOB, the incisors are typically already extruded as a natural compensation. In such patients, excessive incisor extrusion to camouflage the existing skeletal deformity is undesirable and considered unstable.[18] The treatment plan is determined on the basis of the amount of maxillary incisor exposure, lip incompetency, and anterior facial height. In contrast, molar intrusion can relapse as well. Thirty percent of maxillary molar relapse with compensatory maxillary incisor extrusion and labioversion of mandibular incisors was reported in open bite patients treated by molar intrusion with fixed appliances.[19] In this study, clear aligner treatment resulted in 94% stability, higher than previously reported with fixed appliance treatment.[5-8,20-22] This might be because clear aligner treatment held the vertical dimension rather than opening the mandibular plane with conventional fixed appliance treatment.[23] In this study, only 2 patients experienced a maximum of 1 mm of maxillary molar extrusion, whereas only 1 patient showed 1.1 mm of mandibular molar extrusion during treatment. Most patients experienced either molar intrusion or minimal molar extrusion of <0.5 mm. A previous study demonstrated that maxillary molar intrusion using clear aligners contributed 15% in AOB closure.[12]

As a result, less incisor extrusion was required to close the bite. Specifically, 75% of the patients required <2 mm of maxillary incisor extrusion, and 70% required <2 mm of mandibular incisor extrusion to achieve positive overbite. Relative extrusion of incisors through retroclination also contributed to the vertical change of the incisors. Most of the patients in the study had mild crowding, and interproximal reduction and arch expansion were used to resolve crowding and retrocline the anterior teeth. Another reason for increased stability can be that the study sample's open bite severity was mostly mild to moderate (Table I), with 58% having <2 mm and 31% having >3 mm of open bite.

There was no correlation between initial overbite and open bite relapse during retention. This result is in accordance with previous research stating that there was no correlation between the decrease of overbite during the retention period and the initial open bite severity or the amount of open bite correction.[20] Although there was no correlation between initial overbite and the

Table II. Comparison of cephalometric measurements at T1 and T2 (n = 52)

Measurements	*T1*	*T2*	*Changes (T2 − T1)*	P *value*
MPA (°)	39.55 ± 7.29 (26.70-54.20)	39.00 ± 7.11 (26.70-52.20)	−0.55 ± 0.90 (−2.40 to 1.40)	<0.0001
LFH (mm)	72.41 ± 5.35 (60.10-83.80)	71.63 ± 5.43 (60.10-82.80)	−0.79 ± 1.08 (−3.40 to 1.20)	<0.0001
IIA (°)	125.76 ± 10.03 (101.30-145.30)	135.53 ± 8.50 (118.10-152.80)	9.77 ± 7.48 (−10.30 to 28.10)	<0.0001
U1SNA (°)	101.61 ± 7.65 (84.00-115.80)	96.41 ± 6.80 (79.30-111.90)	−5.19 ± 4.82 (−16.50 to 4.00)	<0.0001
IMPA (°)	93.08 ± 7.41 (75.60-106.00)	89.06 ± 8.38 (67.40-103.10)	−4.02 ± 5.28 (−16.00 to 18.50)	<0.0001
Open bite (mm)	−2.23 ± 1.48 (−5.60 to −0.50)	1.10 ± 0.72 (0.10-3.10)	3.33 ± 1.54 (1.40-8.50)	<0.0001
Overjet (mm)	3.13 ± 2.22 (−3.10 to 10.80)	2.61 ± 0.60 (1.50-3.90)	−0.51 ± 2.18 (−9.00 to 4.80)	0.09
U6-PP (mm)	24.99 ± 2.52 (20.60-30.40)	24.43 ± 2.51 (19.70-29.50)	−0.57 ± 0.70 (−2.50 to 1.00)	<0.0001
U1-PP (mm)	29.55 ± 2.75 (23.40-37.00)	30.73 ± 3.00 (23.90-37.90)	1.19 ± 0.99 (−1.20 to 3.50)	<0.0001
L6-MP (mm)	33.46 ± 2.90 (28.50-40.90)	33.42 ± 2.85 (28.60-41.10)	−0.04 ± 0.54 (−1.60 to 1.10)	0.86
L1-MP (mm)	37.89 ± 3.50 (30.50-44.90)	39.25 ± 3.80 (32.20-46.70)	1.36 ± 1.24 (−3.40 to 3.90)	<0.0001

Note. Values are presented as mean ± standard deviation (range).

Table III. Comparison of cephalometric measurements at T2 and T3 (n = 52)

Measurements	*T2*	*T3*	*Changes (T3 − T2)*	P *value*
MPA (°)	39.00 ± 7.11 (26.70-52.20)	38.94 ± 7.16 (26.10-52.80)	0.12 ± 0.44 (−0.80 to 1.60)	0.50
LFH (mm)	71.63 ± 5.43 (60.10-82.80)	71.67 ± 5.49 (60.10-83.90)	0.12 ± 0.49 (−1.10 to 1.40)	0.73
IIA (°)	135.53 ± 8.50 (118.10-152.80)	136.77 ± 8.59 (118.10-154.00)	1.24 ± 2.90 (−9.30 to 5.60)	0.34
U1SNA (°)	96.41 ± 6.80 (79.30-111.90)	95.82 ± 7.11 (79.30-114.50)	−0.59 ± 1.73 (−3.50 to 4.40)	0.56
IMPA (°)	89.06 ± 8.38 (67.40-103.10)	88.31 ± 8.33 (67.40-103.20)	−0.78 ± 1.83 (−3.20 to 5.30)	0.40
Overbite (mm)	1.10 ± 0.72 (0.10-3.10)	1.28 ± 0.85 (−1.20 to 3.80)	0.18 ± 0.50 (−1.50 to 1.00)	0.59
Overjet (mm)	2.61 ± 0.60 (1.50-3.90)	2.73 ± 0.61 (1.10-4.00)	0.12 ± 0.47 (−2.00 to 0.80)	0.87
U6-PP (mm)	24.43 ± 2.51 (19.70-29.50)	24.44 ± 2.53 (19.70-29.70)	0.01 ± 0.23 (−0.90 to 0.50)	0.99
U1-PP (mm)	30.73 ± 3.00 (23.90-37.90)	30.82 ± 3.05 (24.50-37.90)	0.09 ± 0.32 (−0.70 to 0.70)	0.75
L6-MP (mm)	33.42 ± 2.85 (28.60-41.10)	33.39 ± 2.80 (28.70-41.10)	0.03 ± 0.31 (−0.90 to 0.90)	0.93
L1-MP (mm)	39.25 ± 3.80 (32.20-46.70)	39.46 ± 3.77 (32.50-47.00)	0.18 ± 0.46 (−1.20 to 1.30)	0.43

Note. Values are presented as mean ± standard deviation (range).

amount of relapse in this study, further investigation of more severe open bites is necessary to confirm this result.

We were not able to predict treatment stability using cephalometric measurements at pretreatment, change in cephalometric variables during treatment, or retention time. Among the factors that possibly affect open bite relapse, the most critical factor is tongue posture problem. At T3, 3 patients relapsed with overbites of −0.1, −0.4, and −1.2 mm, respectively; all presented with interincisal tongue positions. Most evidence points to nonadaptation of the tongue as an explanation of instability.[24] Tongue thrust might not cause an open bite, but tongue tip protrusion during swallowing is sometimes associated with a forward tongue posture.[25,26] Therefore, careful evaluation and myofunctional therapy are needed when treating patients with AOB. Myofunctional therapy in conjunction with orthodontic treatment was reported to be highly effective in maintaining closure of AOB compared with orthodontic treatment alone.[27]

Retention protocol was also considered a factor affecting open bite relapse. Common retention methods include vacuum-formed, Hawley-style, or bonded retainers, and regimens can be classified as full-time or part-time wear.[5] The National Dental Practice-Based Research Network Adult Anterior Open Bite Study revealed that vacuum-formed retainers were the most commonly used type, as clinicians believed that occlusal coverage from vacuum-formed retainers better maintains molar vertical positions.[5] Bonded maxillary and mandibular retainers were the second most commonly used type.[5] In this study, patients had bonded maxillary and mandibular retainers and overlay vacuum-formed retainers worn at nighttime. The retention protocol was standardized for all patients to avoid the impact of confounding factors on the stability. Because all patients in this study followed 1 retention protocol, comparing stability depending on different retention types was not possible. Only 1 patient reported wearing vacuum-formed retainers <2 nights/wk. Eight patients had their bonded retainers removed during retention. Most patients maintained bonded retainers for at least over a year, whereas only 1 had bonded retainers removed less than a year (at 10 months) after treatment completion. No statistically significant correlation was found between the removal of a fixed retainer and the relapse of AOB (Table V, $P = 0.38$). Two patients had a >1 mm decrease in overbite during retention: one

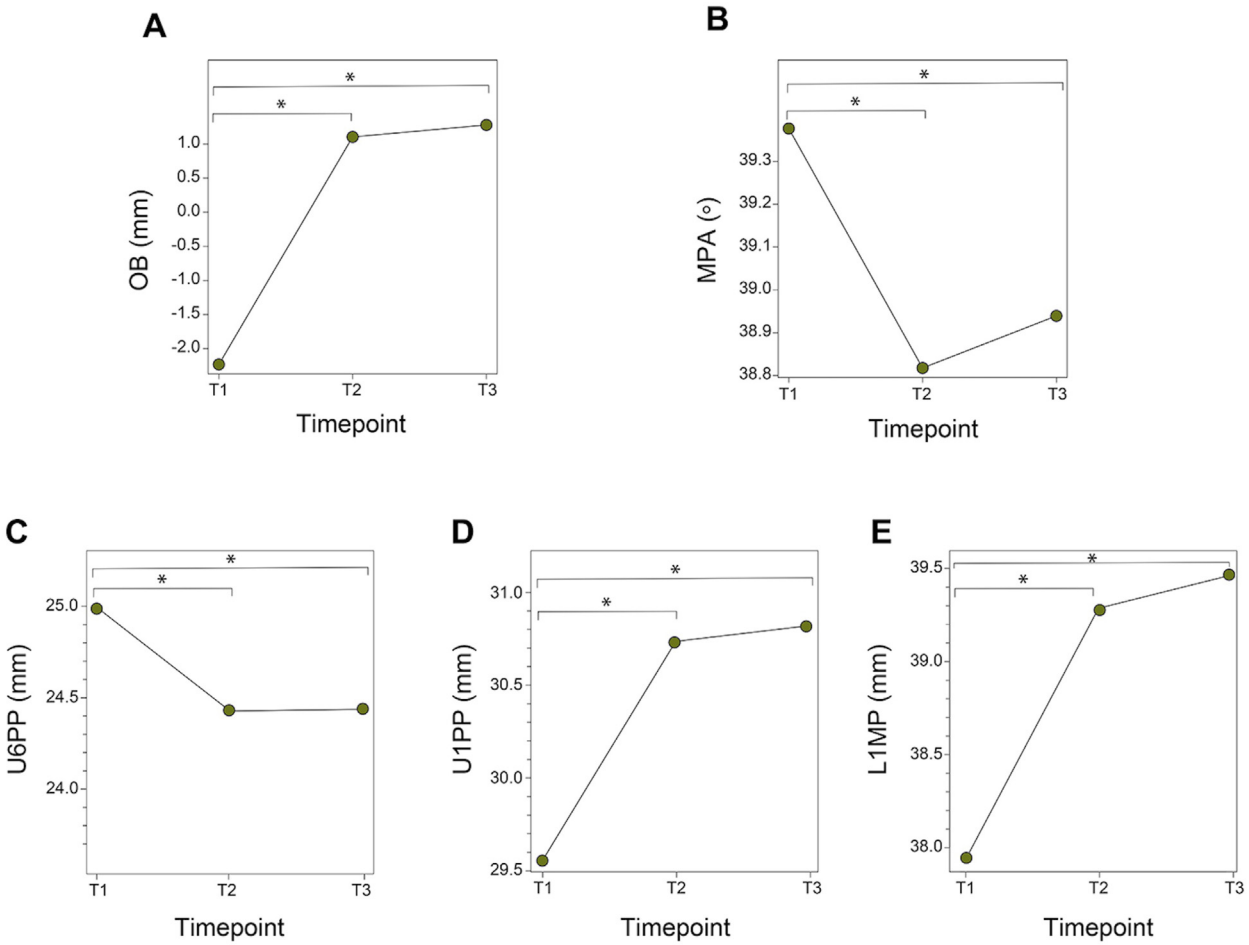

Fig 3. Comparison across 3 time points: **A,** Overbite; **B,** MPA; **C,** Maxillary first molar vertical position; **D,** Maxillary incisor vertical position; **E,** Mandibular incisor vertical position. **C, D,** and **E** are presented on the same scale. Dental intrusion presented as a negative value; dental extrusion presented as a positive value. *Represents significant differences between the groups ($P < 0.05$). See Figure 2 for definitions of each measurement.

had bonded retainers removed 10 months after treatment completion, and the other reported wearing vacuum-formed retainers <2 times/wk. A previous study reported that bonded retainers alone are insufficient, suggesting additional retainers for controlling interarch discrepancy and the vertical dimension.[28] However, further studies are needed to verify this observation.

Similar to every retrospective clinical study, this study had the following limitations: (1) Only patients who returned for retention records were included. About 30% of the patients agreed to take retention records, which included lateral cephalograms. Thus, the sample size was relatively small for a retrospective evaluation, and the characteristics of the included subjects were not controlled; (2) A control group of adult patients with AOB treated with fixed appliances was not available for this study; (3) The retention time for this study was not very long. Fifty-eight percent of patients had a retention time of <2 years, whereas the remaining patients had a 2-5 year retention time. Although previous

Table IV. Statistical significance for the variables incorporated in the model selected by stepwise regression

Variables	P *values*
Intercept	0.81
Initial MPA	0.17
U1 extrusion	0.08
L1 inclination change	0.09
Tongue problem*	0.02

*$P < 0.05$.

Table V. Relationship between changes in overbite during retention and predictor variables

	Open bite change during retention	
Variables	*r*	P values
Initial overbite	0.11	0.44
Initial MPA	0.11	0.45
U1 vertical position change	−0.15	0.29
U6 vertical position change	−0.16	0.25
L1 vertical position change	−0.19	0.18
U1 inclination change	0.17	0.22
L1 inclination change	0.19	0.17
Retention time	0.09	0.51
Presence of tongue problems*	−0.29	0.03
Removal of bonded retainer	0.12	0.38
History of orthodontic treatment	0.16	0.25

*P <0.05.

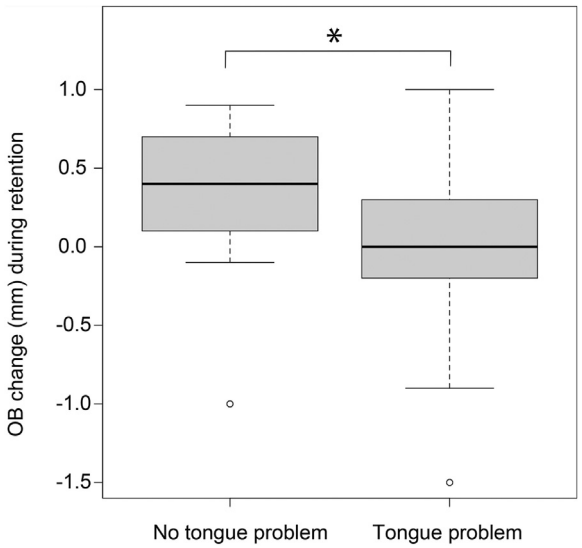

Fig 4. Comparison of overbite change during retention between patients without tongue and those with tongue problems. Tongue problems refer to tongue posture issues identified at the initial examination. *Represents significant differences between the groups (P <0.05).

studies reported that a significant amount of relapse in overbite and molar intrusion occurs during the first year of retention[15] and most relapse occurs during the first 5 years,[27] a long-term stability study compared with the fixed appliance group is warranted; (4) There was insufficient systematic documentation of tongue habits, function, and posture. Therefore, a systematic evaluation of oral habits and function should be included in addition to conventional diagnostic records for future AOB treatment studies.[27,29]

CONCLUSIONS

1. All patients achieved positive overbite after clear aligner treatment (mean change of 3.3 mm) through a combination of extrusion of anterior teeth and <1 mm of posterior intrusion.
2. When retained with maxillary and mandibular bonded retainers and vacuum-formed retainers are worn nightly, 6% of patients presented with relapse at least 1 year after treatment completion.
3. Initial overbite, initial MPA, amount of incisor extrusion during treatment, incisor inclination changes during treatment, history of treatment, retention time, and removal of fixed retainers did not show any statistically significant correlations with overbite change during retention.
4. Tongue posture or interincisal tongue position might be an important consideration for stability.

AUTHOR CREDIT STATEMENT

Heeyeon Suh contributed to conceptualization, investigation, formal analysis, and original draft preparation; Bella Shen Garnett contributed to conceptualization, resource, and manuscript review and editing; Kimberly Mahood contributed to resources and manuscript review and editing; Robert L. Boyd contributed to conceptualization and manuscript review and editing; Heesoo Oh contributed to supervision, conceptualization, methodology, and manuscript review and editing.

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