Anterior Openbite Malocclusion in Adults: Treatment Stability and Patient Satisfaction

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Abstract

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Introduction: Anterior openbite (AOB) malocclusion is challenging for practitioners to both treat and maintain treatment outcomes. There are many orthodontic treatment and retention modalities used to treat AOB patients, but there is no consensus on which modalities are most successful or stable. This study aims to investigate the overall stability of AOB orthodontic treatment approximately one year after treatment in an adult population distributed across the United States, as well as factors that influence treatment stability. Factors that are associated with patients' satisfaction with treatment are also described.

Methods: Practitioners and their adult AOB patients were recruited through the National Dental Practice-Based Research Network. Patient dentofacial and demographic characteristics, practitioner demographic and practice characteristics, and factors relating to orthodontic treatment have been reported previously. Treatment stability was determined from end-of-treatment and post-treatment intraoral photographs.

Patient satisfaction was determined from end-of-treatment and post-treatment questionnaires using five-point Likert-type scales and open-ended responses. Treatment was categorized into four main groups: aligners, fixed appliances, temporary anchorage devices (TADs), and orthognathic surgery. The effect of extraction of teeth on treatment outcomes was also investigated. Retention type was categorized into Essix-style, Hawley-style, or bonded retainers and regimens were classified as full-time or part-time wear.

Results: Retention data were collected from 112 patients who had been in retention for at least 9 months since the end of active treatment. The mean post-treatment time was 1.21 years (SD= 0.34 years). There were no statistically significant differences in stability between treatment groups. Overall 89% of patients maintained positive overbite (as measured on the right central incisors) and 65% maintained overlap of all incisors. Extractions exhibited a trend to be associated with higher stability. High satisfaction was reported by patients at one-year post-treatment. There were no significant differences in stability or satisfaction between retention types or regimens.

Conclusion: The stability of orthodontic treatment in adult AOB patients who participated in this study was high, regardless of treatment modality. Stability tended to be higher for patients who had extractions than those who did not. Additionally, the satisfaction in adult AOB patients was also high, regardless of retention type and regimen.

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INTRODUCTION

Anterior open bite (AOB) is defined as a condition in which the maxillary and mandibular incisors are not in contact when a patient occludes on the posterior teeth. The prevalence of AOB has been found to be about 3% in an adult Caucasian American population, but the prevalence of AOB can range widely from 1.5% to 11% depending on ethnic group and dental age[1]. The percentage of AOB patients in an orthodontic setting may be as high as 17%[2]. AOB has been historically considered one of the more challenging malocclusions to correct[3]. This difficulty in treatment can be attributed to AOB's complex etiology, which may be from skeletal, dental, respiratory, neurologic, habitual, or combined factors[4]. Additionally, patient satisfaction associated with the treatment and retention of AOB malocclusion has not been evaluated. In the past few decades, there has been increased interest in patient quality of life[5,6], especially for orthodontics where the goals are to enhance patient quality of life through correction of malocclusion[7,8].

Most practitioners are able to treat AOB successfully, but maintaining positive overlap after treatment can be difficult[9]. Todoki, et al. reported that 84% of a large sample of AOB patients achieved positive vertical overlap of all four incisors at the end of treatment, and 93% had positive overbite as assessed by the central incisors on post-treatment cephalometric radiographs. Greenlee and colleagues conducted a meta-analysis on the stability of AOB treatment and concluded that surgical and non-surgical treatment both appeared to exhibit greater than 75% stability, defined as positive incisor overlap at 12 or more months post-treatment[11]. Ideally, practitioners would like to achieve 100% long-term stability in corrected malocclusions. Treatments for AOB can include aligners, full fixed appliances, orthognathic surgery, behavior-modifying appliances (when tongue thrusting or thumb sucking habits are present), temporary anchorage devices, or any combination of the above[11, 13]. Although there is considerable literature on the treatment of AOB and its immediate post-intervention results, there is less literature on the stability of AOB treatment. Greenlee's meta-analysis included twenty-one studies that assessed stability, but most had relatively low scores for study quality[11]. Importantly, many of the orthodontic studies reported only

on adolescents, and many of the surgical studies only included adults. Thus, literature on non-surgical treatment in adult AOB patients is sparse. Due to the increasing popularity of aligners and TADs, it is important to investigate their success and stability in AOB patients.

In 2015, the National Dental Practice-Based Research Network (PBRN) Anterior Openbite Study was initiated. The purpose of this large, multicenter, prospective cohort study was to explore non-surgical and surgical treatment recommendations, outcomes, stability, and satisfaction in adult AOB patients. The study had three phases: Enrollment (T1), End-of-Active Treatment (T2), and One-Year Post-Treatment (T3). This publication reports on the overall stability rate of AOB treatment at T3, patient satisfaction, and factors that might influence stability and satisfaction.

MATERIALS AND METHODS

Dental providers and their adult AOB patients were recruited for this study from across the United States, specifically from the six regions of the National Dental PBRN (West, Midwest, Southwest, South Central, South Atlantic, and Northeast). Approval from three Institutional Review Boards (IRBs) were obtained for this study: University of Alabama IRB on behalf of the Central, Midwest, Southwest, and South Central regions, Kaiser Permanente IRB for the Western region, and the University of Rochester Research Subjects Review Board for the Northeastern region.

Inclusion Criteria for Practitioners at time of enrollment:

- Orthodontist or dentist who routinely performs orthodontic treatment
- Expects to recruit three to eight adult patients in active treatment for AOB and complete treatment within 24 months of study enrollment
- Routinely takes cephalometric radiographs before and after treatment
- Able to upload de-identified cephalometric radiographs and digital intraoral frontal photographs to a central data repository

- Affirms that the practice can provide sufficient time in patient scheduling to allow recording of all required data for the study
- Does not anticipate retiring, selling the practice, or moving during the study

Inclusion Criteria for Patients at time of enrollment:

- At least 18 years of age (so that growth is not a confounding factor, especially with surgery patients tending to wait until growth is complete)
- Must have AOB malocclusion, defined as one or more incisors that do not have vertical overlap with teeth in opposing arch. The remaining incisors may exhibit minimal incisor overlap, but none can contact the teeth in the opposing arch. This was determined by the practitioner through examining the patient's initial cephalometric radiograph, intraoral photos, and/or initial plaster or digital casts
- Must be in active treatment for AOB malocclusion and expected to complete treatment within 24 months of study enrollment
- Must have initial cephalometric radiograph (obtained prior to the start of treatment). A cephalometric radiograph generated from a cone-beam CT scan was acceptable

Exclusion Criteria for Patients at time of enrollment:

- Clefts, craniofacial conditions or syndromes
- Lack of pre-treatment and end-of-treatment radiographs
- Significant physical, mental, or medical conditions that would affect treatment compliance, cooperation, or outcome, as determined by the treating dentist/orthodontist

Only adult patients 18 years of age or older were recruited to the study to minimize the effects and influences of facial growth on treatment outcome. Practitioners were requested to enroll all eligible patients to avoid selection bias, with a maximum of 15 patients per practitioner. If a practitioner had more than 15 eligible patients, the patients were sequentially selected based on their treatment start dates.

At Enrollment (T1), practitioners and patients completed questionnaires to report information about practitioner characteristics, patient characteristics, pre-treatment diagnosis, and recommended/accepted treatment. Practitioners and patients also completed questionnaires at End-of-Active Treatment (T2) to report information about the treatment process and treatment results, including any changes to the accepted treatment plan. At One-Year Post-Treatment (T3), practitioners and patients completed questionnaires to report information about AOB stability. Additionally, patient satisfaction was assessed using five-point, Likert-type scales and open-ended responses at both T2 and T3. The questionnaires were sent to regional data collection centers, where they were reviewed for accuracy and completeness prior to uploaded into a centralized database. All study forms and questionnaires can be accessed at http://nationaldentalpbrn.org/anterior-openbite-malocclusions-in-adults-recommendations-treatment-and-stability.php.

Intraoral frontal photographs from all time points were de-identified and forwarded to the research team at the University of Washington. The Photographic Openbite Severity Index (POSI) was developed by Huang, et al.[14] to score the severity of a patient's open bite based on the intraoral frontal photographs (Figure 1). This index is useful for grading AOB severity at all three of the study's time points. The POSI has seven categories, defined by the type and number of teeth that do not have vertical overlap. Figure 1 shows examples of POSI scores 1 through 6.

0. All four incisors exhibit vertical overlap (No Anterior Open Bite)
1. One or two maxillary lateral incisors without vertical overlap, but both maxillary central incisors have vertical overlap
2. One maxillary central incisor without vertical overlap, but the other maxillary central incisor has vertical overlap
3. Both maxillary central incisors lack vertical overlap but at least one maxillary lateral incisor has vertical overlap
4. All four maxillary incisors lack vertical overlap

5. All anterior teeth, including canines, lack vertical overlap
6. All anterior teeth, including canines, and at least one premolar lack vertical overlap

A POSI score of 0 represents treatment success at T2 and treatment stability at T3. At T3, POSI scores between 1-2 represent mild relapse, while POSI scores between 3-6 represent significant relapse.

Additionally, millimetric overbite at T2 and T3 were calculated using the intraoral frontal photos, as cephalograms were not obtained at T3. The method for measuring the millimetric photographic overbite from the photos is described below in the Appendix.

At T3, the proportion of treated AOB malocclusion exhibiting treatment stability was calculated. Stability at this time was measured by the two methods described above – POSI and millimetric overbite calculated from the photographs. A POSI score of 0 or a positive post-treatment overbite measured on the photographs were considered stable.

POSI scores at T3 were assessed by two raters, and the overbite measurements and calculations were performed by one assessor. For POSI scoring, disagreements in ratings were resolved by means of consensus between the examiners. To calculate intra and inter-rater reliability for T3 POSI, twenty T3 intraoral frontal images were randomly selected and millimetric measurements and POSI scores were determined.

Inter-rater reliability of the T3 POSI scores was 95% between the two raters (DG and LT). The intra-rater reliability of the POSI measurements for measurements by the same rater (DG) one month apart was 95%. The intra-rater reliability of the millimetric measurements showed a linear regression R^2 of .9562 for measurements by the same rater one month apart. The correlation coefficient of the T2 millimetric calculated photographic overbites based on the intraoral photographs compared to the T2 overbites based on the cephalometric radiographs was r=0.80.

Practitioners and patients enrolled in the study received incentives for their participation and time. Practitioners received $100 for each study phase visit per patient completed and patients received $25 for T1, $25 for T2, and $50 for T3.

DATA ANALYSIS

Practitioner and Patient Characteristics

Demographic Characteristics

The enrollment questionnaires provided practitioner and patient demographic characteristic data. Practitioner characteristics included age, gender, race and ethnicity, specialization, country of dental school, years in practice, geographic region of practice, and practice type. Patient characteristics included age, gender, race and ethnicity, insurance coverage, education level, and previous orthodontic treatment.

Dentofacial characteristics that were reported by the practitioner included profile, angle molar classification, maxillary and mandibular arch length, posterior crossbites, and habits such as tongue or finger habits. Cephalometric values were obtained from pre- and post-treatment cephalometric radiographs.

Treatment Stability was based on POSI scores and millimetric overbite, as stated earlier.

Treatment stability rates were calculated overall, as well as by the following factors:

A. Treatment modality (Aligners, fixed appliances, TADs, orthognathic surgery)
B. Extractions
C. Retention type (Essix-style, Hawley-style, fixed)
D. Retention regimen (Full-time, part-time)

In addition, multivariate analyses were performed when sample sizes were adequate.

A. Treatment Modality

Treatment modality was determined based on enrollment and post-treatment questionnaires. Any changes to the original treatment plan were ascertained in the post-treatment questionnaire.

Four mutually exclusive treatment categories were identified for this study, arranged in order of increasing invasiveness and ability to treat complex malocclusions:

1) Aligners (no fixed appliances, temporary anchorage devices (TADs), or orthognathic surgery)
2) Fixed appliances (no TADs or orthognathic surgery)
3) TADs (with no orthognathic surgery)
4) Orthognathic surgery

The ordering of the treatment groups allowed patients who received multiple treatments to be characterized into the most invasive treatment category. For example, a patient treated with both aligners and fixed appliances would be categorized into the fixed appliances group.

B. Extractions

When premolars or anterior teeth were removed as part of the orthodontic treatment, patients were classified as having extractions. Patients who had third molars removed were not classified as extraction patients unless other teeth, such as premolars or incisors, were extracted.

C. Retention Type

Retention modality was ascertained from the end of treatment practitioner questionnaire.

The provider selected one of the retention categories for each arch:

1) Hawley-style or circumferential-style
2) Essix-style (clear overlay shell)
3) Bonded retainer
4) Other (provider specified)

D. Retention Regimen

Retention regimen was ascertained from the end of treatment practitioner questionnaire.

The provider selected one of the retention regimen categories for each arch:

1) Full-time (Wearing at all times except when eating, drinking, or brushing)
2) Part-Time (Typically, night-time use)
3) Other (provider specified)

A bonded retainer was automatically considered full-time.

Treatment Duration and Retention Duration

Treatment duration was calculated using the date of initial orthodontic appliance placement at T1 and the date of appliance removal at T2. Retention duration was calculated using the date of appliance removal at T2 and the date of the final retention visit T3.

Patient Satisfaction

Patient satisfaction at T3 was assessed using a five-point, Likert-type scale (very satisfied, somewhat satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied, and very dissatisfied). Patients rated their satisfaction on their self-perception of their overbite, overall retainer experience, retainer type, retainer-wear regimen, appearance of teeth, biting/chewing, and overall satisfaction with their orthodontic treatment. Patients were able to provide open-ended explanations to expand upon responses when they reported to be somewhat dissatisfied or very dissatisfied.

Satisfaction rates were calculated by grouping the responses into a dichotomous *Satisfied* versus *Not Satisfied*. The *Satisfied* category included the responses of very satisfied and somewhat satisfied. The *Not Satisfied* category included responses of neither satisfied nor dissatisfied, somewhat dissatisfied, and very dissatisfied.

Statistics and Predictive Models

Descriptive statistics were performed on the patient and practitioner sample. P-value significance was set at 0.05 for statistical analysis. Overall stability rates were calculated based on the following outcome measures:

1) Positive overbite (mm) calculated from T3 intraoral photographs
2) T3 POSI=0, indicating positive overlap of all anterior teeth

Stability rates were obtained for treatment modality, retainer type, and retainer regimen.

Multivariable predictive models and regression analysis were planned to identify factors related to stability satisfaction if sample sizes were adequate.

RESULTS

In total, 91 practitioners and 347 patients were recruited for the study from October 2015 to June 2016. (Figure 2) Data at T2 were collected from 84 practitioners and 254 patients through December 2018. The rest of the patients had either withdrawn from the study (N=24) or did not complete orthodontic treatment within the study period (N=63). Patients who were missing T2 cephalometric data were excluded from cephalometric analysis, leaving a total of 231 patients for the T2 cephalometric analysis. Patients missing T2 intraoral images and other T2 data were excluded from POSI analysis, resulting in a total of 232 patients for the POSI analysis at T2.

Data at T3 were collected for 164 patients. However, 52 of these patients were excluded, as their post-treatment time was less than 9 months, leaving 112 patients with 9 months or more of post-treatment time. Figure 3 shows the distribution of patients by number of days since end of treatment. Patients who were missing T3 intraoral images or other T3 data were excluded from the POSI analysis. Data from patients who were missing intraoral photos or had poor quality intraoral images (N=28) were excluded from millimetric overbite analysis.

At T3, 93 patients had complete POSI T2 and T3 data. In the stability analyses, we further restricted the sample to only those who were successfully treated to POSI=0 at T2. With this restriction, the number of patients in the sample decreased from 93 to 80. Initial practitioner characteristics are summarized in Table 1 and initial patient characteristics can be seen in Table 2. In Table 1, we can see that the practitioner characteristics of the T2 (N=254), T3 (N=112), and T3 complete POSI data (N=93) do not significantly differ from the original sample at T1. We can also see that the initial patient dentofacial characteristics and cephalometric values of the T2, T3, and T3 with complete POSI data are also very similar to the initial patient demographics, dentofacial characteristics, and cephalometric values of the original sample at T1.

When the sample was restricted to those with successful treatment (T2 POSI = 0), the overall mean overbite at T3 (N=80) was 1.34 (SD=0.93), as seen in Table 3. We observed an 89% stability rate evaluated by positive photographic overbite >0 at T3 and a 65% stability rate when evaluated by a T3 POSI=0.

For those patients with minimum 9 months retention, the average overall treatment time (Table 4) observed was 1.78 years (SD=0.83 years). The average overall retention time observed was 1.21 years (SD= 0.34 years).

For completeness, we report the final T2 and T3 POSI scores for all patients that had complete POSI data (Table 5). There were 13 patients who were not treated to POSI=0 at T2. For the 9 patients who finished treatment with a POSI=1, 6 of them maintained POSI=1 by T3. One patient worsened to POSI=4, and 2 patients improved to POSI=0 by T3. All patients (N=4) who were treated to POSI=1, 2, or 3 maintained their respective T2 POSI scores at T3.

Treatment Modality

The overall millimetric T3 overbite was 1.34 mm. Both the aligner and TAD groups had mean overbites greater then the overall average (Table 3). Similarly, the overall stability rate based on POSI was 65%,

but both the aligner and TAD groups exhibited higher rates of stability. However, the sample sizes for aligner and TAD groups were small, and these differences did not reach statistical significance.

Extractions

When restricting to the group of 80 patients with T2 POSI = 0, 7 patients underwent extraction. Six were in the fixed appliances group, and 1 was in the surgery group. The mean treatment duration for extraction treatment was 2.47 years (SD=1.04 years), while the mean treatment duration for non-extraction treatment was 1.67 years (SD=0.77 years) (Table 4). Of the seven extraction patients, 71% maintained a POSI=0 at T3 and 100% maintained a positive overbite, while in the non-extraction patients (N=73), 64%maintained a POSI=0 at T3 and 88% maintained positive overbite. (Table 3)

Retainer Type and Regimen

Of the minimum 9 months retention patients, 224 arches had retainer type data: 26 were prescribed Hawley-style, 127 were prescribed Essix-style, 26 were prescribed bonded retainers, and 45 were categorized as other (Table 6). Retainer type combinations for the 80 patients with T2 POSI = 0 were grouped into the 3 most common: Essix-style upper/lower (N=37), Essix-style upper/Hawley-style lower (N=10), bonded upper/lower (N=9) and other (N=24). The less common combinations made up the remaining 24, such as Essix-style upper/other lower (N=7), bonded upper/Hawley-style lower (N=2), and other upper/bonded lower (N=2) as a few examples. There was a combination of other upper and lower in 9 patients. These “other” designations often meant dual retention with a bonded and removable retainer in the same arch. Aligner patients were almost exclusively prescribed Essix-style retainers.

Table 7 provides a summary of the overall stability, and stability across different treatments, retainer types, and retention regimens. There were no statistically significant differences in stability between full-time and part-time wear, or between upper and lower arch stability. Thus, maxillary and mandibular regimens were combined together into full-time wear regimen or both arches (N=41), which had an overall 61% stability, and part-time wear in at least one arch, which had 69% stability.

In our sample of 80 patients, the stability ranged from 57% for surgery patients (N=14) to 83% for the TADs group (N=6; see Table 7). Fixed appliances (N=48) had a 63% stability rate and clear aligners (N=12) had a 75% stability rate.

Satisfaction

We assessed satisfaction overall, as well as by treatment and retention factors (Table 8). Patients expressed a 96% satisfaction rate with their overall orthodontic treatment experience and a 96% satisfaction rate with their retainer experience. Additionally, most patients (86% - 98%) reported being satisfied with the positive-overbite self-assessment, retainer type, treatment duration, appearance, and ability to bite/chew.

The extraction patients had an overall 82% satisfaction rate with their orthodontic treatment, while 97% of patients without extractions reported being satisfied with their orthodontic treatment. For the other satisfaction measures (self-perception of positive overbite, retainer experience, retainer type, retainer regimen, appearance and biting/chewing), extraction patients' satisfaction ranged from 70% to 91%, while the non-extraction patients' satisfaction ranged from 82% to 98%.

Due to the small number of dissatisfied patients, there was insufficient statistical power to investigate differences in satisfaction based on various factors.

Open-Ended Responses

There were 7 open-ended responses from patients who reported dissatisfaction, but they addressed unique situations that were not useful for analyses.

Predictive Models

Based on the small numbers of patients with aligners, TADs, and surgery, multivariate linear models were developed to predict treatment stability only in the fixed appliances patients. We included initial overbite, initial mandibular plane angle, initial lower incisor proclination, extractions, and residual habits in the

model (Table 9). Based on these models, lower POSI scores at T3 were associated with less severe initial openbite, lower incisor to mandibular plane values, and extractions. When millimetric overbite was the outcome, deeper overbite at T3 was associated with lower incisor to mandibular plane values and extractions.

DISCUSSION

This study evaluated the overall treatment stability and satisfaction of adult AOB patients treated in the United States. With respect to millimetric overbite, our rate of 89% stability is slightly higher than that reported by Greenlee, et al[11]. Janson[26] reported that stability decreases as the amount of time since end-of-active treatment increases, and perhaps these patients will exhibit lower stability in the years to come. It is also possible that the study setting influenced both practitioners and patients to employ robust retention methods, which may help to explain the relatively good stability. This is evidenced by 13 patients being prescribed both fixed and removable retention in the same arch.

If stability is defined as POSI=0, the stability rate in our sample is only 65%. POSI = 0 requires all 4 incisors to have positive overlap, so this is a stricter definition than the millimetric measurement we employed, which was based only on the right central incisors.

The only treatment group large enough for predictive model analysis was the fixed appliances group, which contained 60% (N=48) of the 80 patients with T2 POSI = 0. Additionally, this group contained 6 of the 7 extraction patients. It was interesting that less initial lower incisor proclination and extractions were associated with better stability using both POSI and millimetric overbite as the outcome variables. In Todoki's study[10], initial lower incisor angulation was also associated with higher treatment success, and Janson, et al. have reported that extraction treatment is more stable in adolescent AOB patients[26].

Most practitioners prescribed patients both upper and lower Essix-style retainers. Dental providers may feel that Essix-style retainers are better for AOB treatment retention due to the presumed molar intrusive effects from their occlusal coverage. Adult orthodontic patients may prefer Essix-style retainers, as they

are a more esthetic retainer option. Ramazanzadeh et al. reported that Essix-style retainers seem to be more effective at maintaining arch length and tooth alignment in the upper arch than Hawley-style retainers, although there was no significant difference between the two types of retainers for lower arch retention[18]. Another study by Demir, et al. found that the retention characteristics of both Essix-style and Hawley-style retainers are similar, with the Essix-style retainers more effective in maintaining mandibular incisor positions.[25]

We did not find a significant difference in stability between full-time vs part-time retainer regimens. This was surprising since we would think that full-time retainer wear should be more stable than part-time wear. Castle and colleagues investigated patient compliance with Hawley-style retainers outfitted with Bluetooth data trackers and saw that their patient sample was fairly compliant with regimen instructions[16]. A recent study by Vagdouti and colleagues found that there was high patient compliance with both Hawley-style and Essix-style retainers. They also found that Essix-style retainers were better accepted by patients[17]. However, we did not obtain data to confirm that patients wore their retainers as requested, and it is possible that the amount of wear when a full-time or part-time regimen was requested was similar. Also, the retention time of our study may have been too short for stability differences to manifest. The study was designed with a retention period for one year, but long-term retention data of 5 or more years might be more useful in truly understanding stability in these patients.

High levels of satisfaction were observed in the T2 post-treatment data, as reported by Finkleman and colleagues[15]. They found that 96% of patients reported being satisfied with the orthodontic treatment provided as well as the final esthetic and functional results. At T3, we find that patients still maintain high levels of satisfaction one year after completion of treatment.

Patients reported a 96% satisfaction rate with the retainer experience and 94% satisfaction with their retainer type. Unfortunately, there were not enough Hawley-style and bonded retainer patients to perform comparisons in satisfaction between the different types of retainers. It is interesting to note that the clear aligner group demonstrated 100% satisfaction with retainer experience, type, and appearance. This could

be related to all of them receiving Essix-style retainers, which would be very similar to the clear aligners that were used during treatment.

The high levels of satisfaction might be attributed to the continuation of overall positive experiences the patients have with orthodontic treatment. As found by Pacheco-Pereira et al, the current literature describes high levels of contentment and satisfaction with orthodontic care.[20] Their systemic review concluded that satisfaction after orthodontic treatment was strongly associated with perceived esthetic outcomes and dissatisfaction after orthodontic treatment was associated with discomfort or pain, and problems with usage of retention appliances. The patients in our study, due to the overall high stability rates, were probably still satisfied at T3 due to their perceived esthetic outcome. Additionally, since few patients reported negative issues with their retention appliances, it suggests that they were satisfied with retention overall. Reidmann and colleagues[21] reported 97% of patients were satisfied with their orthodontic treatment outcome; Lee and colleagues[22] reported satisfaction rates of 84.9% to 92.6% in adult patients. These high satisfaction rates with orthodontic treatment could easily carry over into retention, especially with overall high stability. Another study described high levels of patient satisfaction that most strongly correlated to the doctor-patient relationship[23]. In Finkleman's study, patients reported numerous positive comments about the practitioners and their staff[15]. A recent study[24] by Maia, et al. reports high long-term patient satisfaction with orthodontic treatment.

For further studies, it would be important to obtain as much data as possible from the patients who did not meet the data collection deadline for T3. A data collection extension has been requested, which if granted, would significantly boost our sample sizes for both T2 and T3.

LIMITATIONS

We acknowledge that this study had several limitations. Some limitations, such as the nonrandom nature of the patient and practitioner sample, were inherent in the design of the study. However, Todoki and colleagues (2019) reported that the demographics of the practitioner sample were similar to the American

Association of Orthodontists membership with the exception of there being a greater number of practitioners in academic settings. To minimize selection bias, practitioners were asked to enroll all patients who met the inclusion criteria.

Another limitation is the non-random nature of treatment and retention regimen/type. Practitioners selected both the treatment and the retention protocol for the patient, which resulted in uneven distributions of treatments and retention strategies. However, this study does provide a snapshot of adult AOB treatment strategies being used across the United States from 2015 -2018.

Additionally, the completeness of our follow-up data was another limitation. Although there was some patient attrition by the T3 time point, the biggest reason for incomplete follow-up was that the funding period for the network grant ended.

A potential limitation of the POSI scoring system is that photographs need to be taken parallel to the occlusal plane. If not, the assessment of incisor overlap may not be accurate. To minimize these issues, all offices were instructed and calibrated on the correct orientation for intra-oral photos prior to the initiation of the study.

CONCLUSIONS

At a minimum of 9 months post-treatment, the stability rate based on millimetric overbite was 89% for adult patients who received orthodontic treatment for AOB malocclusion. When the POSI index was used, stability dropped to 65%. There were no statistically significant differences in stability rates based on the different treatment modalities. Only the fixed appliance group was large enough for multivariate analyses, which indicated that less initial lower incisor proclination and extraction therapy were associated with higher stability. There were no statistically significant differences in stability rates between different retainer types and regimens, but sample sizes were not large. Overall, patients continued to report high levels of satisfaction one year after treatment.

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Figure 1. Photographic Openbite Severity Index (POSI)

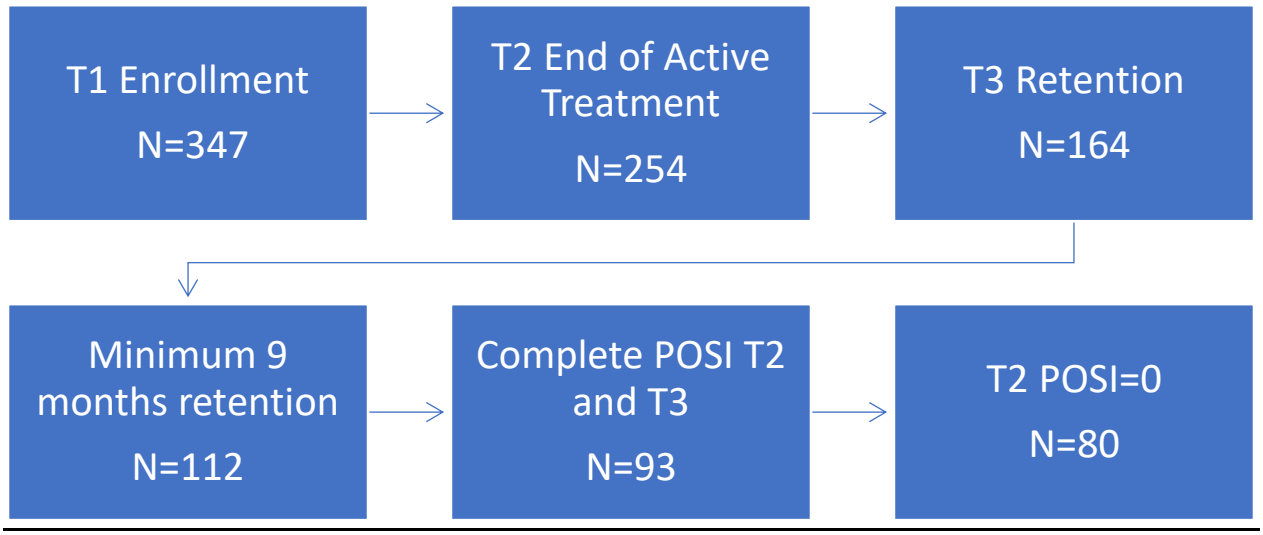

Figure 2. Patient Sample

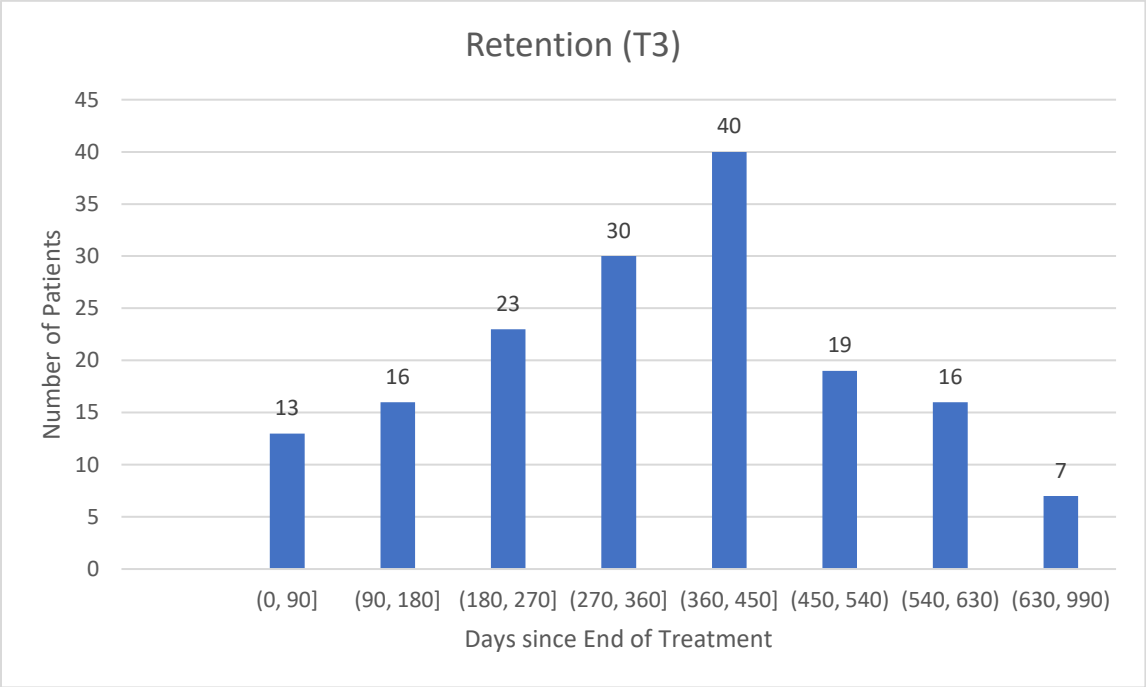

Figure 3. Distribution of patients based on days since end of treatment

Table 1. Initial Practitioner Characteristics at T1, T2, T3 with minimum 9 months retention, and T3 minimum 9 months retention and complete POSI data

Practitioner Characteristics	**T1 N=345**	**T2 N=254**	**T3 N=112**	**T3 with complete POSI data N=93**
Gender				
Male	74%	73%	75%	74%
Female	26%	27%	25%	26%
Race and Ethnicity				
White/Caucasian	58%	60%	63%	64%
Asian	29%	28%	21%	18%
Hispanic	11%	9%	13%	16%
Other/Unknown	2%	2%	4%	2%
Age, years				
<45	39%	39%	38%	33%
45-54	23%	24%	26%	27%
55-64	32%	30%	29%	32%
≥65	7%	6%	7%	9%
Geographic Region of Practice				
West	47%	48%	54%	52%
Midwest	10%	10%	5%	6%
Southwest	11%	11%	14%	15%
South Central	6%	4%	3%	2%
South Atlantic	11%	13%	13%	14%
Northeast	16%	13%	11%	11%

Table 2. Initial Patient Demographics, Dentofacial Characteristics, and Cephalometric Values at T2, T3 with minimum 9 months retention, and T3 with minimum 9 months retention and complete POSI data

	T1	**T2**	**T3**	**T3 with complete POSI data**
Patient Demographics	**N=345**	**N=253**	**N=112**	**N=93**
Gender				
Male	26%	25%	26%	27%
Female	74%	75%	74%	73%
Age, years				
18-20	17%	17%	8%	10%
21-30	45%	42%	35%	35%
31-40	22%	23%	33%	31%
≥41	16%	18%	24%	24%
Race and Ethnicity				
White/Caucasian	55%	58%	63%	63%
Black/African-American	10%	9%	5%	4%
Asian	8%	9%	9%	9%
Multirace	4%	3%	4%	3%
Hispanic	23%	21%	19%	21%
Previous Orthodontic Treatment				
Yes	39%	42%	51%	53%
No	61%	58%	49%	47%
Initial Patient Dentofacial Characteristics				
Arch Length (Severest of maxillary or mandibular)				
No Crowding	20%	19%	21%	21%
Mild Crowding (1-3mm)	35%	40%	44%	50%
Moderate Crowding (4-6mm)	31%	31%	25%	19%
Severe Crowding (>6mm)	14%	10%	10%	10%
Tongue Thrust and Tongue Posture				
Yes	12%	11%	13%	16%
No	88%	89%	87%	84%
Initial POSI				
1-3	32%	33%	13%	16%
4-6	68%	%67	63%	65%
Initial Patient Cephalometric Values	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
MPSN: Mandibular Plane Angle	38.8 (7.2)	38.5 (7.1)	38.1 (7.2)	38.3 (7.5)
U1 to NA	25.6 (8.3)	25.8 (8.7)	25.3 (8.7)	25.2 (8.9)
IMPA (Mn incisor angulation to MP)	94.9 (8.8)	94.8 (8.5)	95.7 (7.7)	95.8 (7.8)
Overbite (mm)	-2.4 (2.2)	-2.4 (2.1)	-2.0 (1.7)	-2.1 (1.7)

Table 3. Overbite and POSI at T3 for Patients with T2 POSI=0

	Overall N=80	**Aligner N=12**	**Fixed Appliances N=48**	**TADs N=6**	**Surgery N=14**	**Non-extraction N=73**	**Extraction N=7**
T3 Mean Overbite (mm) (SD)	1.34 (0.93)	1.77 (0.51)	1.14 (0.95)	1.76 (0.86)	1.55 (1.04)	1.32 (0.92)	1.49 (1.06)
T3 Overbite>0	89%	100%	85%	100%	90%	88%	100%
T3 POSI=0	65%	75%	63%	83%	57%	64%	71%

Table 4. Treatment and Retention Times, minimum 9 months retention

	Overall	Aligners	Fixed Appliances	TADs	Surgery	Non-extraction	Extraction
Treatment Time in years (SD)	1.78 (0.83)	1.52 (0.52)	1.90 (0.88)	2.25 (0.99)	1.43 (0.70)	1.67 (0.77)	2.47 (1.04)
Retention Time in years (SD)	1.21 (0.34)	1.23 (0.33)	1.19 (0.33)	1.21 (0.33)	1.28 (0.41)	1.18 (0.31)	1.48 (0.48)

*SD=Standard Deviation

Table 5. T2 and T3 POSI Scores (Minimum 9 months retention and complete POSI data)

POSI at T2	Number of Patients	POSI at T3						
		0	**1**	**2**	**3**	**4**	**5**	**6**
0	80	52	22	2	0	4	0	0
1	9	2	6	0	0	1	0	0
2	2	0	2	0	0	0	0	0
3	1	0	0	0	1	0	0	0
4	1	0	0	0	0	1	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
Total	93	54	30	2	1	6	0	0

Table 6. T3 Retention Type and Regimen, minimum 9 months retention

		Maxilla (N=112)				**Mandible (N=112)**			
Retainer Type	Overall Total	Full-time	Part-time	Not Specified	Total	Full-time	Part-time	Not Specified	Total
Hawley-style	26	0	0	3	3	1	1	21	23
Essix-style	127	47	29	0	76	28	23	0	51
Bonded	26	13	0	0	13	13	0	0	13
Other	45	9	11	0	20	11	14	0	25

Table 7. T3 Stability for patients with T2 POSI=0

	Overall		**Clear Aligners (N=12)**		**Fixed Appliances (N=48)**		**TADs (N=6)**		**Surgery (N=14)**	
	% Stable	Mean Overbite	% Stable	Mean Overbite	% Stable	Mean Overbite	% Stable	Mean Overbite	% Stable	Mean Overbite
Overall (N=80)	65%	1.34 (0.93)	75%	1.77 (0.51)	63%	1.14 (0.95)	83%	1.76 (0.86)	57%	1.55 (1.04)
Regimen (N=80)										
Full Time Upper and Lower (N=41)	61%	1.40	67%	2.22	59%	1.20	75%	1.82	57%	1.79
Part Time Upper or Lower (N=39)	69%	1.26	78%	1.61	67%	1.07	100%	1.67	57%	1.32
Retainer Type										
Essix-style upper/lower (N=37)	68%	1.37	86%	2.00	64%	1.20	NA	NA	50%	2.43
Essix-style upper, Hawley-style lower (N=10)	70%	1.38	NA	NA	80%	1.83	100%	1.10	33%	0.81
Bonded upper/lower (N=9)	56%	1.52	100%	1.97	0%	0.55	50%	1.89	100%	2.37
Other (N=24)	63%	1.21	50%	1.39	67%	1.00	100%	1.70	50%	1.54

Table 8. T3 Patient Satisfaction

		Treatment						Retention			
Satisfaction Measure	Total	Clear Aligners	Fixed Appliances	TADs	Surgery	Non-Extraction	Extraction	Essix-style Upper and Lower	Essix-style Upper, Hawley-style Lower	Bonded Upper and Lower	Other
Overall Orthodontic Treatment	96%	93%	95%	100%	100%	97%	82%	93%	100%	100%	97%
Positive Overbite	86%	93%	80%	100%	94%	82%	70%	80%	90%	100%	94%
Retainer Experience	96%	100%	95%	100%	94%	95%	82%	95%	100%	100%	94%
Retainer Type	94%	100%	89%	100%	100%	91%	82%	91%	100%	100%	94%
Treatment Duration	94%	100%	89%	100%	100%	91%	73%	93%	100%	100%	90%
Appearance	97%	100%	96%	100%	94%	95%	91%	98%	90%	100%	97%
Biting and Chewing	98%	93%	98%	100%	100%	98%	91%	98%	100%	89%	100%

Table 9. Regression analysis restricted to Fixed Appliances, T2 POSI=0

	T3 POSI			**T3 Overbite**		
	Estimated Effect	Standard Error	P	Estimated Effect	Standard Error	P
Initial Overbite (mm)	-.0185	0.068	0.01	0.053	0.069	0.44
Initial Mandibular Plane (deg)	0.030	0.034	0.38	0.037	0.020	0.07
Initial L1MP (deg)	0.045	0.023	0.05	-0.033	0.013	0.01
Extraction	-0.941	0.441	0.03	0.832	0.333	0.01
Residual Habits	0.198	0.322	0.54	-0.360	0.233	0.12

Appendix.

Two intra-oral frontal photographs were taken at T2 and T3 to measure overbite.

- One photo was taken in maximum intercuspation while the other was taken with incisors apart so that the full height of the lower incisors could be measured.
- The millimetric height of the right maxillary incisor at T2 and T3 was recorded by the clinician at the respective time point and used to calculate the magnification factor.
- All photos were cropped to exactly contain the width of the four maxillary incisors, with a set image size of 6 inches in length. After which, the height of maxillary right central incisor and the length of the visible portion of the lower right central incisor were measured on the image.

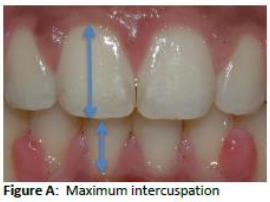

Figure A: Maximum intercuspation

Figure B: Incisors apart

- Both Figure A and Figure B images are 6 inches in length. In Figure A, the measured maxillary right incisor height is 61mm and the height of the mandibular right central incisor is 36mm. In Figure B, as the view of the mandibular central incisor not obstructed by the incisor above it, its height is 43mm.
- The *magnification factor* was calculated by dividing 61mm (height of maxillary right incisor as measured in the photograph by the research team) by 15.3 (height of maxillary right incisor as measured clinically and reported by the treating practitioner) = 3.99.
- The *overbite measurement before magnification adjustment* was calculated by subtracting 36mm (height of lower incisor in maximum intercuspation as measured in the photograph) from 43mm (height of lower incisor with teeth apart as measured in the photograph) = 7mm.
- The *photographic overbite value* was calculated by dividing the overbite measurement by the magnification factor. Thus, 7mm divided by 3.99 = 1.8 mm of overbite.