Comparison of Outcomes in Adolescents Treated with Aligners versus Fixed Appliances in an Academic Setting

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ABSTRACT
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Background: Adolescents are increasingly requesting and being treated with aligners, and there is a need for better information regarding treatment indications and outcomes in this population. **Purpose:** The aims of this study were to compare treatment efficacy and efficiency, presence and extent of new or larger white spot lesions (WSL), and oral health-related quality of life (OHRQOL) in adolescent patients treated with aligners versus fixed appliances (FA) in an academic dental clinic. **Study Design:** This cohort study was carried out in the University of Washington (UW) Graduate Orthodontics clinic. 29 adolescent subjects (18 male and 11 female, mean age = 14) treated with aligners and fulfilling the inclusion criteria were recruited and matched 1:1 with adolescent subjects treated with FA. Pre-treatment characteristics were collected, and subjects were contacted to complete a modified OHIP-14 questionnaire to evaluate their OHRQOL. Treatment efficacy was assessed by comparing the peer assessment rating (PAR) scores and treatment efficiency was assessed by comparing the number of emergency visits, de-bonded appliances, appointment visits, and treatment time. Presence and extent of new or larger WSLs were assessed evaluating the incisors from the digital photos using the ImageJ software. **Results:** The two groups had similar demographic and pre-treatment parameters, as well as post-treatment PAR scores. There was a trend for less de-bonded appliances in the aligner group (mean A = 1.0 vs. FA = 3.0 appliances; $p = 0.07$), but no significant difference in the treatment time. However, participants in the aligner group had significantly less treatment visits (mean A = 15.7 vs. FA = 21.3 visits; $p < 0.001$) and emergency visits (mean A = 0.4 vs. FA = 1.0 visits; $p = 0.01$). Participants in the aligner group had significantly fewer maxillary incisors with new or larger WSLs ($p = 0.02$), and oral hygiene counselling was provided three times less frequently ($p = 0.01$) compared to participants in the FA group. Lastly, the groups had similar total OHIP-14 scores, but only 26% of participants in the aligner group reported occasional interruption of meals versus 70% of participants in the FA group ($p = 0.02$). **Conclusions:** This study found both groups had similar PAR outcomes and treatment times. However, participants in the aligner group had fewer emergency visits, treatment visits, de-bonded appliances, new or larger WSLs, and interruption of meals compared to participants in the FA group.

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DEDICATION

I would like to dedicate my success to my family who have supported and believed in me up to this point. I would especially like to thank my mother, Yayoi, and father, Russell, for nurturing me into the person I am today and shaping me with the values I hold dearly. I could not have been more fortunate to have you two as my parent. I would also like to show my appreciation to my sister, Tiana, who always supported me unconditionally throughout my life and being a great role model I look up to. Lastly, I would like to send my appreciation to all my co-residents, faculty, and mentors who made my time here at UW Orthodontics a fun and enjoyable experience.

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INTRODUCTION

Fixed orthodontic appliances (brackets and bands) have been the most popular option to treat malocclusions for over a century.[1] Although effective for orthodontic treatment, difficulty with oral hygiene and esthetic preferences are two limitations of fixed appliances (FA). The terms “railroad tracks” or “tinsel teeth” are commonly used to describe patients’ smiles during treatment. However, some patients develop white spot lesions (WSL) during treatment due to poor oral hygiene, which can mar the appearance of the teeth for a lifetime.[2]

Aligner treatment is an alternative therapy that mitigates most of the hygienic and esthetic disadvantages of FA.[2-7] Aligner therapy in its current form emerged around the year 2000, as companies developed 3D CAD-CAM technology that allowed good control over the planning and fabrication of a series of aligners.[8] This development made aligners more widely available as a practical treatment option for many patients. As its use continues to increase, it is essential to understand the advantages and disadvantages of aligners compared to FA to better provide evidence-based, personalized treatment recommendations to patients.[9]

There is considerable literature comparing outcomes between FA and aligners, focusing on treatment efficacy and efficiency, WSLs, and oral health-related quality of life (OHQOL), mostly in adults.[2-18] For example, there have been reports of adult patients with mild malocclusion treated with aligners requiring five more months of treatment time compared to FA, with both groups finishing with similar results.[10] However, Borda et al. reported conflicting results,

with their teenage aligner group finishing six months earlier than the FA group.[11] The authors ascribed the shorter treatment duration in the aligner group to the fewer number of emergency and total visits, as well as their ability to begin anterior-posterior and vertical discrepancy correction immediately. Their observation is supported by another study reporting shorter treatment duration with aligners.[12] Papageorgiou et al. conducted a systematic review that included 11 studies assessing the treatment efficacy in adult patients with mild to severe malocclusion treated with either aligners or FA. They concluded that FA therapy had better treatment outcomes based on the American Board of Orthodontics Objective Grading Score (ABO-OGS), but similar outcomes based on PAR.[13]

The presence and extent of WSLs in patients treated with aligners and FA has been investigated in previous studies. [2-7] White spot lesions are characterized by enamel surface and subsurface demineralization without any cavitation caused from long term plaque retention.[2] Once formed, the affected enamel presents with a chalky appearance that may be noticeable and unesthetic to orthodontic patients' post-treatment. There are discrepancies in the current literature regarding the development of new WSLs when patients are treated with aligners versus FA. Alshatti et al. observed no significant differences in the incidence and severity of WSLs when comparing young adults (21 ± 11 years old) treated with aligners to adolescents (14 ± 4 years old) treated with conventional FA in a university clinic setting.[3] This is supported by Chhibber et al.'s randomized controlled trial finding no significant difference in oral hygiene levels among adolescents treated with aligners or FA.[4] On the other hand,

Albhaisi et al. and Buschang et al. both observed an increased incidence of WSLs in adult patients treated with aligners versus FA.[5,6] Their findings are consistent with Raghavan et al.'s meta-analysis reporting aligner patients having significantly less WSLs, plaque accumulation, and salivary caries-associated bacteria compared to FA patients.[7] The discrepancies may be due to the varying study designs, evaluation methods, and patient characteristics.

It is important to consider patient-reported outcomes related to comfort and well-being, and OHRQOL represents such a factor. Jaber et al. observed that patients treated with aligners had a less negative impact to their OHRQOL when compared to patients treated with FA.[14] In that study, patients treated with FA reported that difficulties with eating were the most significant issue, while speech problems were an issue in the initial stages of treatment. The researchers also observed that patients treated with aligners reported significantly less pain, which is supported by other studies that also concluded an overall higher quality of life experienced by patients with aligners.[15-19]

There is a growing body of literature addressing aligners and, to date, inconsistencies may be due to considerable development and improvement in the aligner software, materials, and techniques over the past two decades. Importantly, much of the existing literature has investigated treatment in adult patients with relatively little focus on adolescent patients. Adolescents are increasingly requesting and being treated with aligners, and there is a need for better information regarding treatment indications and outcomes in this population. Therefore, the purpose of this study was to assess the differences in

1) treatment efficacy and efficiency, 2) presence and extent of new or larger WSLs, and 3) OHRQOL for adolescent patients completing treatment with aligners versus FA between 2019 and 2024 in an academic dental clinic.

METHODS

Participants, Eligibility Criteria, and Setting:

Adolescent orthodontic patients (18 years or younger at treatment initiation) who completed comprehensive treatment with only aligners or only FA between 2019-2024 at the University of Washington (UW) Orthodontics Clinic were included in the study. All patients were treated with either non-extraction (n=57) or 1 lower incisor extraction (n=1) plans, and they had a full set of initial and final records (composite photo, digital scan, and lateral cephalometric radiograph) of good quality. Patients who were treated using both aligners and FA were excluded from the study, as were patients with premolar extractions, syndromes, severe disabilities, systemic diseases, periodontitis, oral lesions, or history or current use of medications (i.e. bisphosphonates, corticosteroids).

Intervention:

Approval from the Institutional Review Board was obtained from the UW Human Subjects Division prior to conducting this cohort study on June 30, 2023 (STUDY00017664). The UW patient database was screened for all aligner patients who met the inclusion criteria from January 2019 through June 2024. The authors then consecutively selected individuals treated with FA who also met the inclusion criteria, matching on age (± 1 year), gender, pre-treatment upper

and lower arch length (± 2mm), and pre-treatment PAR score (± 5 points). Once the samples were matched, patient consent was sought to use their clinical records for this study as well as to complete a questionnaire assessing OHRQOL.

Patients who completed treatment prior to the initiation of the study were invited to participate in the study at their retention visit or over a phone call and patients who completed treatment later were invited to participate at their retainer delivery visit. A standardized script was followed for recruitment of all potential participants and a $30 gift card was offered as compensation. If interested, participants were consented, and the modified Oral Health Impact Profile-14 (OHIP-14; Appendix, p. 32) was administered. Past studies used the OHIP-14 questionnaire to assess the OHRQOL after orthodontic treatment.[20] This widely used, validated questionnaire includes 14 questions that measure the patient's quality of life based on their functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap.[21] As there are currently no existing OHRQOL assessment tools tailored for orthodontic patients, the original version of the questionnaire was modified by replacing the word "denture" with "orthodontic treatment" in each question.[22]

After patients were enrolled as study participants, their chart notes and records (composite photos, digital scan, lateral cephalometric radiograph) were used to complete the patient data abstraction form (Appendix, p 33). This form included information on the participant's gender, age, ethnicity, disabilities, type

of insurance, treatment plan (extraction or non-extraction), pre-treatment crowding/spacing, and other information pertaining to the case. Pre- and post-treatment intra-oral photos were used to measure the presence and extent of new or larger WSLs.

Treatment efficacy was evaluated by a graduate orthodontic student (DO) and an orthodontic faculty (GH). They were both calibrated in using the UK-weighted PAR scoring system according to Richmond et al.[23] Pre- and post-treatment PAR index measurements were made digitally on MyCadent software using the participant's pre- and post-treatment study casts. The assessors were blinded to the treatment group when performing the measurements. Treatment efficiency was assessed by recording the participant's overall treatment time, number of emergency visits, number of de-bonded appliances, and number of visits (abstracted from the chart notes).

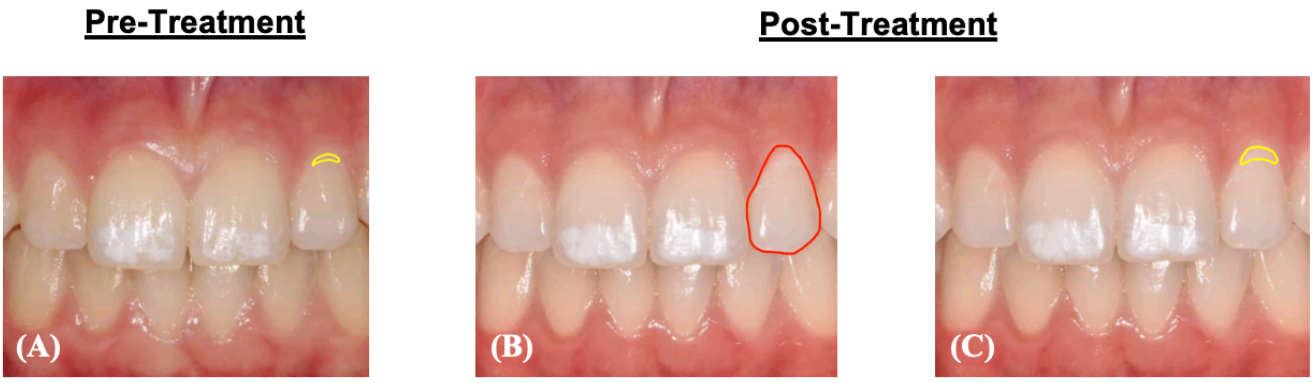

Fig 1. Initial photo used to assess pre-existing WSL area (A), Final photos used to assess total post-treatment tooth surface area in red (B), and the new WSL surface area in yellow (C) on the ImageJ software.

Pre- and post-treatment intraoral photos were used to measure the presence and extent of new or larger WSLs. The digital photographs were

matched for magnification and color using Adobe Photoshop prior to assessment. All 4 maxillary incisors were judged for the development of new WSLs during treatment. A WSL was also considered new or larger if a new cavitation developed during treatment, or if it progressed to the point that a restoration was placed during treatment. In all participants who were initially assessed to have new or larger WSLs, a panel of 3 assessors reviewed each case to reach a consensus that a new or larger WSL had developed. The surface area of new or larger WSLs was assessed using ImageJ software by calculating the percent surface area of the WSLs on the 4 maxillary incisors (Figure 1) according to the formula:

$$Percent\ Surface\ Area\ of\ New\ or\ Larger\ WSL = \frac{Total\ Surface\ Area\ of\ New\ or\ Larger\ WSL\ on\ all\ Maxillary\ Incisors}{Total\ Surface\ Area\ of\ all\ Maxillary\ Incisors}$$

The pre-treatment surface area of the WSLs was subtracted from the post-treatment surface area of the WSLs before making the percentage calculations. WSL measurements were taken twice for all teeth, and the average of the two values was used for analysis.

Sample Size Calculation:

A power calculation for the sample size was carried out for the mean difference in the percent of teeth that developed new WSLs. A prior study reported 24.5% more patients with new WSLs when adults were treated with FA versus aligners (25.7% versus 1.2%).[12] Using their findings, the power to detect a 24.5% difference in WSL formation was 0.80 with 29 subjects per group. Thus, the minimum target of 29 participants in each group provided adequate power to

detect a clinically significant difference in WSLs for these two groups of participants.

Statistical Analyses:

Univariate descriptive tests were performed for the pre-treatment characteristic assessment of the two groups. Paired-samples t-tests were used for continuous variables, McNemar's tests for the categorical variables, and the Wilcoxon sign-ranked test was performed when data were not normally distributed.

To assess differences in PAR between the two groups, a paired-samples t-test was used to compare post-treatment scores. The total number of visits, emergency visits, and de-bonded appliances were statistically evaluated using the Wilcoxon sign-ranked test while the total treatment time was assessed using the paired-samples t-test. The proportion of participants with new or larger WSLs in both groups was evaluated using McNemar's test. The proportion of teeth with new or larger WSLs, number of times each participants received oral hygiene instructions, and the percent surface area of the new or larger WSLs on the maxillary incisors in all participants were assessed using the Wilcoxon sign-ranked test. To compare the differences in OHRQOL between the groups, a two-samples t-test was conducted using total scores obtained from the modified OHIP-14 questionnaire. Additionally, the Fisher's exact test was used to evaluate between-group differences in responses to individual OHIP-14 questions.

Reliability Measurements:

To evaluate the inter- and intra-examiner reliability for the PAR, assessments for the pre- and post-treatment PAR scores were repeated for 10 randomly selected subjects after 4 weeks. The intraclass correlation coefficient (ICC) and Dahlberg's error calculation were performed between the initial and repeated measurements. Inter- and intra-examiner reliability were excellent, with an ICC of 0.95 and 0.98, respectively, and Dahlberg's measurement errors of 2.5 and 1.0, respectively. The intra-examiner reliability for the post-treatment PAR was also excellent, with an ICC of 0.98 and a Dahlberg's measurement error of 0.5.

For the assessment of presence and extent of WSLs, the intra-examiner reliability was assessed by repeating measurements for all participants 4 weeks after the initial evaluation. The intraclass correlation coefficient (ICC) and Dahlberg's error calculation were performed between the initial and repeated measurements; excellent intra-examiner reliability was demonstrated, with an ICC of 1.0 and 0.99, respectively.

RESULTS

Participant Flow:

Figure 2 shows the participant flow for this study. A total of 29 participants treated with aligners meeting the inclusion criteria were enrolled. Twenty-three of the 29 participants consented for and completed the modified OHIP-14 questionnaire; 6 participants were unable to be contacted. Twenty-nine participants treated with FA meeting the inclusion criteria were then consecutively matched with the participants in the aligner group. Twenty of the 29 participants consented for and completed the modified OHIP-14 questionnaire; 9 participants were unable to be contacted.

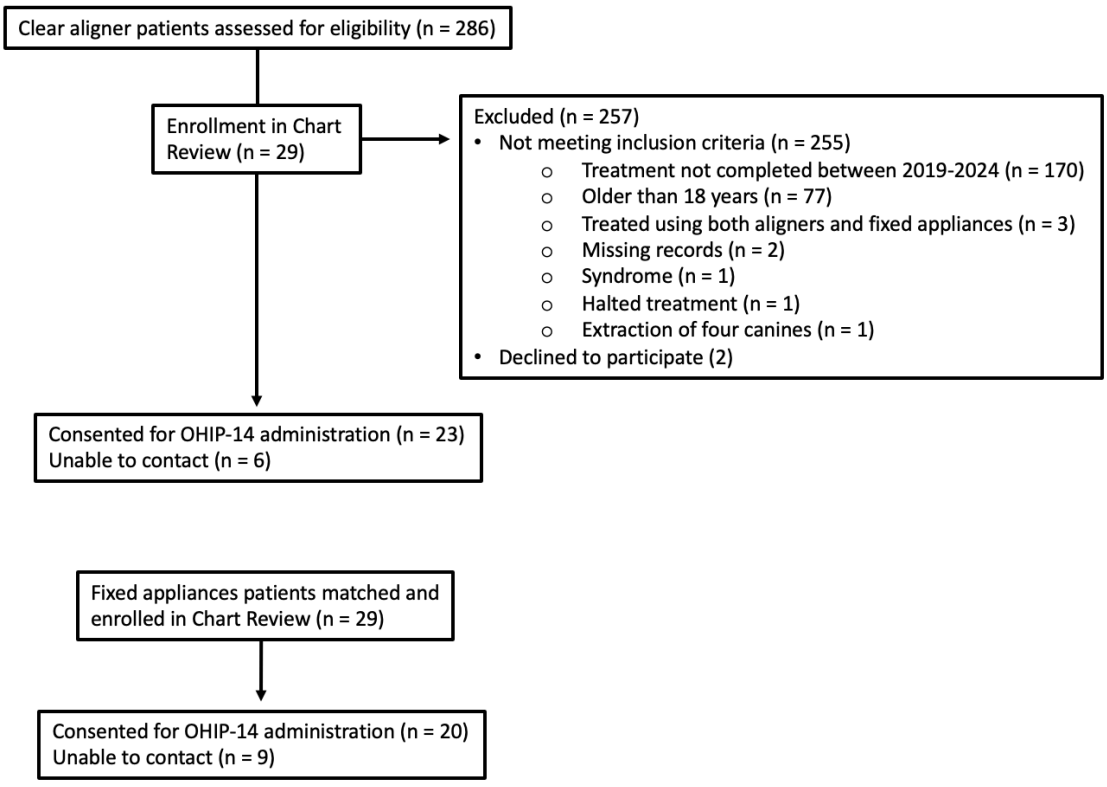

Fig 2. Diagram showing the flow of the subjects.

Pre-Treatment Characteristics Assessment:

Table I shows the pre-treatment characteristics for all participants. Each group consisted of 18 males and 11 females with a mean age of 13.9 ± 2.0 years. All participants had non-extraction treatment except for one participant in the FA group with a lower incisor extraction. The majority of participants had mild crowding/spacing and Class I/Class II half-cusp molar classifications, while the rest had moderate crowding/spacing and Class II/Class III full cusp molar classifications. Otherwise, there was an even distribution of participants with similar pre-treatment characteristics and no significant differences between the groups.

Table I. Pre-treatment characteristics of participants in the aligner and FA group.

	Aligner (n = 29)	Fixed Appliance (n = 29)	p-value
Gender	Female = 11 Male = 18	Female = 11 Male = 18	>0.999[1]
Age	Mean (SD) = 13.9 (1.9) Min, Max = 11.0, 18.0	Mean (SD) = 13.9 (2.0) Min, Max = 11.0, 18.0	0.326[2]
Race/Ethnicity	African American = 3 Asian = 3 Caucasian = 15 Hispanic = 6 Mixed = 2	African American = 4 Asian = 5 Caucasian = 16 Hispanic = 4 Mixed = 0	>0.999[1]
Disability	Cognitive = 5 Physical = 0	Cognitive = 2 Physical = 0	0.248[1]

Insurance Coverage	Medicaid = 18 Private Pay = 11	Medicaid = 21 Private Pay = 8	0.547[1]
Treatment Plan	Non-Extraction = 29 Extraction (lower incisor) = 0	Non-Extraction = 28 Extraction (lower incisor) = 1	>0.999[1]
Pre-Treatment PAR Score	Mean (SD) = 23.4 (8.7) Min, Max = 4.0, 39.0	Mean (SD) = 24.1 (9.1) Min, Max = 8.5, 44.0	0.307[2]
Pre-Treatment Upper Arch Length	Mild Crowding = 19 Moderate Crowding = 5 Spacing = 5	Mild Crowding = 18 Moderate Crowding = 4 Spacing = 7	0.842[1]
Pre-Treatment Lower Arch Length	Mild Crowding = 15 Moderate Crowding = 12 Spacing = 2	Mild Crowding = 19 Moderate Crowding = 6 Spacing = 4	0.198[1]
Pre-Treatment Oral Hygiene	Poor = 2 Fair = 10 Good = 17	Poor = 1 Fair = 12 Good = 16	>0.999[1]
AP Molar Classification	Class I = 17 Class II Half Cusp = 10 Class II Full Cusp = 2 Class III = 0	Class I = 15 Class II Half Cusp = 8 Class II Full Cusp = 5 Class III = 1	0.644[1]
Overjet (mm)	Mean (SD) = 4.2 (1.6) Median (IQR) = 4.0 (3.0, 5.0)	Mean (SD) = 3.1 (3.0) Min, Max = 4.0 (2.0, 4.0)	0.098[3]
Overbite (mm)	Mean (SD) = 3.4 (1.7) Median (IQR) = 4.0 (2.0, 4.0)	Mean (SD) = 3.5 (2.5) Median (IQR) = 3.0 (2.0, 4.0)	0.663[3]

Crossbite	Anterior Crossbite = 7 Posterior Crossbite = 1 Both = 0	Anterior Crossbite = 6 Posterior Crossbite = 4 Both =3	0.267[1]
Mandibular Plane Angle (SN/MnP)	Mean (SD) = 31.7 (7.2) Median (IQR) = 32.6 (26.7, 36.0)	Mean (SD) = 31.0 (7.7) Median (IQR) = 30.5 (25.0, 38.0)	0.732[2]

Note. SD = Standard deviation. IQR = Interquartile range. [1]McNemar's test p-value. [2]Paired t-test p-value. [3]Wilcoxon sign-ranked test p-value.

Treatment Efficacy:

As presented in Table II, there were no significant differences in the final PAR scores between the two groups (A = 5.8 vs. FA = 7.1; p = 0.16), suggesting similar treatment efficacy.

Table II. Post-treatment PAR scores for participants in the aligner and FA group.

	Aligner (n = 29)	Fixed Appliance (n = 29)	p-value
Post-Treatment PAR	Mean (SD) = 5.8 (4.1) Median (IQR) = 5.0 (3.0, 7.0) Min, Max = 1, 17	Mean (SD) = 7.1 (3.6) Median (IQR) = 6.0 (4.0, 10.0) Min, Max = 1, 13	0.155*

Note. SD = Standard deviation. IQR = Interquartile range. *Paired t-test p-value.

Treatment Efficiency:

There was a trend for the participants in the aligner group to have a fewer number of de-bonded appliances (A = 1.0 vs. FA = 3.0 appliances; p = 0.07). There were no significant differences in the treatment time (A = 22.8 mo vs. FA = 23.7 mo), non-adherence to inter-arch elastics (A = 5 participants vs. FA = 9 participants; p = 0.22) and missed appointments (A = 10 participants vs. FA = 14

participants; p = 0.26) between the two groups (Table III). However, there were significant differences in the total number of visits (A = 15.7 vs. FA = 21.3 visits; p < 0.001) and emergency visits (A = 0.4 vs. FA = 1.0 visits; p = 0.01) with the aligner group having on average fewer visits for both (Table III).

Table III. Treatment efficiency data for participants in the aligner and FA group.

	Aligner (n = 29)	Fixed Appliance (n = 29)	p-value
Total Treatment Time (mo)	Mean (SD) = 22.8 (6.2) Median (IQR) = 22.0 (18.0, 27.0) Min, Max = 12.0, 40.0	Mean (SD) = 23.7 (4.0) Median (IQR) = 24.0 (21.0, 27.0) Min, Max = 16.0, 30.0	0.525[2]
Total Treatment Visits	Mean (SD) = 15.7 (4.4) Median (IQR) = 15.0 (13.0, 17.0) Min, Max = 9.0, 26.0	Mean (SD) = 21.3 (4.7) Median (IQR) = 20.0 (18.0, 24.0) Min, Max = 11.0, 32.0	<0.001[1]
Emergency Visits	Mean (SD) = 0.4 (0.8) Median (IQR) = 0.0 (0.0, 1.0) Min, Max = 0.0, 3.0	Mean (SD) = 1.0 (1.1) Median (IQR) = 1.0 (0.0, 2.0) Min, Max = 0.0, 3.0	0.010[1]
Number of De-bonded Appliances	Mean (SD) = 1.5 (3.0) Median (IQR) = 0.0 (0.0, 2.0) Min, Max = 0.0, 15.0	Mean (SD) = 2.9 (4.0) Median (IQR) = 2.0 (0.0, 4.0) Min, Max = 0.0, 18.0	0.070[1]
Complications	3+ Missed Appointments = 10 Non-adherent with Elastics = 5	3+ Missed Appointments = 14 Non-adherent with Elastics = 9	0.255[2] 0.220[2]

Note. SD = Standard deviation. IQR = Interquartile range. [1]Wilcoxon sign-ranked test p-value. [2]Paired t-test p-value.

ALIGNER GROUP

Fig 3. Pre-treatment (left images) and post-treatment (right images) intra-oral photographs of the three participants in the aligner group with new or larger WSLs out of 29 participants. (A-C) Participants in the aligner group presented in order of greatest percent surface area to least percent surface area of WSLs.

FIXED APPLIANCES GROUP

Fig 4. Pre-treatment (left images) and post-treatment (right images) intra-oral photographs of the nine participants in the FA group with new or larger WSLs. (A-I) Participants in the FA group presented in order of greatest percent surface area to least percent surface area of WSLs.

Presence and Extent of White Spot Lesions:

As presented in Table IV, there was a trend of fewer participants in the aligner group developing at least one new or larger WSLs compared to

participants in the FA group (A = 10% vs. FA = 31% of participants with new WSLs; p = 0.1). The participants in the aligner group had a smaller percent surface area of new or larger WSLs (A = 0.5% vs. FA = 10.2%; p = 0.01) and significantly fewer maxillary incisors with new or larger WSLs (Table IV). Data abstracted from patient charts also indicated that the participants in the aligner group were counselled significantly less often for their poor oral hygiene throughout their treatment (A = 5% vs. FA = 16% of their visits; p = 0.01).

Table IV. Presence and extent of WSL data for participants in the aligner and FA group.

	Aligner (n = 29)	Fixed Appliance (n = 29)	p-value
Patients with New or Larger WSLs	3	9	0.11[1]
Percent surface area of new or larger WSLs in all patients	Mean (SD) = 0.5 Median (IQR) = 0.0 (0.0, 0.0) Min, Max = 0.0, 8.5	Mean (SD) = 10.2 Median (IQR) = 0.0 (0.0, 2.6) Min, Max = 0.0, 65.5	0.014[2]
Distribution of maxillary incisors with new or larger WSLs	None = 26 patients 1 incisor = 1 patient 2 incisors = 0 patients 3 incisors = 2 patients 4 incisors = 0 patients	None = 20 patients 1 incisor = 1 patient 2 incisors = 1 patients 3 incisors = 0 patients 4 incisors = 7 patients	0.021[2]
Number of times each patients received oral hygiene instructions	Mean (SD) = 0.9 (1.4) Median (IQR) = 0.0 (0.0, 2.0) Min, Max = 0.0, 6.0	Mean (SD) = 3.2 (4.0) Median (IQR) = 2.0 (0.0, 5.0) Min, Max = 0.0, 14.0	0.006[2]

Note. SD = Standard deviation. IQR = Interquartile range. [1]McNemar's test p-value. [2]Wilcoxon sign-ranked test p-value.

Oral Health-Related Quality of Life:

There was not a significant difference in the average OHIP-14 score between participants in aligner group and those in FA group, indicating similar OHRQOL (Table V-A). However, significantly fewer participants in the aligner group reported that their meals were interrupted due to problems associated with the teeth during treatment compared to participants treated with FA (A = 26.1% vs. FA = 70% answered “seldom” or “somewhat”; p = 0.02) (Table V-B).

Table V-A. Total score from the OHIP-14 questionnaire for participants in the aligner and FA group.

	Aligner (n = 23)	Fixed Appliance (n = 20)	p-value
OHIP-14 Total Score (0-56)	Mean (SD) = 7.1 (5.0) Median (IQR) = 6.0 (3.0, 10.0) Min, Max = 0.0, 18.0	Mean (SD) = 8.4 (5.8) Median (IQR) = 7.5 (3.5, 12.5) Min, Max = 0.0, 21.0	0.927*

Note. SD = Standard deviation. IQR = Interquartile range. *Two-sample t-test p-value.

Table V-B. Breakdown by the responses for question 8 on the OHIP-14 questionnaire for participants in the aligner and FA group.

	Aligner (n = 23)	Fixed Appliance (n = 20)	p-value
OHIP-14: Question 8	Never (0) = 17 Seldom (1) = 4 Sometimes (2) = 2	Never (0) = 6 Seldom (1) = 9 Sometimes (2) = 5	0.015*

Note. *Fisher’s exact test.

DISCUSSION

This primary goal of this cohort study was to investigate differences in outcomes between adolescent patients treated with aligners versus FA in an academic dental clinic. Regarding treatment efficacy, there was no significant difference between the study groups in post-treatment PAR score. This result is consistent with findings presented in Papageorgiou et al.'s systematic review, which demonstrated no significant differences between aligners and FA group using the PAR index. However, that systematic review did report worse occlusal outcomes for patients treated with aligners compared to patients treated with FA when the ABO-OGS was used.[7] The PAR index is a less precise assessment tool compared to the ABO-OGS, not including variables like posterior tooth alignment, tooth inclinations, and occlusal contact. Despite the differences between the two assessment tools, Yassir et al. and Ke et al.'s studies used the ABO-OGS scoring criteria and reported aligners being as effective as FA for treating mild to moderate malocclusion, with limitations in producing adequate occlusal contact and torque control.[6,24] Papageorgiou et al.'s systematic review included some studies with more severe malocclusions, which could potentially contribute to the inconsistency.[7] Furthermore, our understanding of aligners has significantly improved, allowing us to better manage side effects from using aligners such as occlusal contact issues resulting from posterior open bites. If Papageorgiou et al.'s systematic review included older studies where practitioners did not account for this issue, it could also have influenced their ABO-OGS outcomes.

Treatment efficiency of aligners and FA systems have been investigated in previous studies based on the number of treatment visits, emergency visits, and treatment time. Borda et al. and Chou et al.'s studies compared the outcomes of teenagers with mild to severe malocclusion treated with either appliance. Both studies found that patients treated with aligners had significantly fewer emergency visits (Borda: 0.8 vs. 3.6; Chou: 2.0 vs. 3.0), treatment visits (Borda: 13.7 vs. 19.3; Chou: 16.0 vs. 24.0), and treatment time (Borda: 17.0 mo vs. 23.4 mo; Chou: 24.0 mo vs. 27.0 mo).[5,25] The results of our study are mostly consistent with the findings of those two studies, with participants in the aligner group having fewer treatment and emergency visits. This finding is likely due to participants treated with aligners having less de-bonded appliances and being seen at longer intervals between visits compared to participants treated with FA. Findings related to treatment time for participants in this study differed from findings from past studies. Perhaps the similar total treatment times could be attributed to the academic setting, where graduate students are still developing their skills in both techniques.

In terms of presence and extent of WSLs, a greater proportion of participants treated with FA had new or larger WSLs following treatment than their matched participants with aligners, similar to findings reported by Albhaisi et al. and Buschang et al.[11,12] The notable difference in the development of new or larger WSLs between the treatment groups is further emphasized by the fact that there were significantly fewer incisors affected with WSLs among participants treated with aligners who developed WSLs compared to participants treated with

FA who developed WSLs. Additionally, participants treated with aligners had a significantly lower percent surface area of new or larger WSLs, a 20-fold difference compared to those treated with FA. These results suggest that if a patient receiving orthodontic treatment develops a new WSL, those treated with aligners will develop smaller WSLs on fewer teeth compared to those treated with FA. Furthermore, participants treated with aligners had to be counselled three times less frequently for poor oral hygiene than participants treated with FA, a finding that is consistent with results reported by Raghavan et al., wherein less plaque accumulation was observed among participants treated with aligners versus FA.[14] Although not a parameter of focus in this study, participants treated with aligners were observed to have less post-treatment gingival inflammation (as observed in photographs) than participants treated with FA (Figure 4). Taken together, the findings related to WSLs may be explained by the removable nature of aligners, which allows for better adherence to proper oral hygiene behavior compared to FA. However, for some participants treated with aligners, there may be concerns if patients consume sugary drinks with their trays on, which may result in more diffuse WSLs. There was one participant in the aligner group who developed such diffuse WSLs (Figure 3A), which could be consistent with that theory.

Post-treatment OHRQOL was rated similarly between the two groups, consistent with findings presented by Tunca et al., who showed no significant differences in the quality of life of adolescents with mild to moderate malocclusions treated with aligners versus FA.[26] However, at the item level,

significantly fewer participants treated with aligners compared to FA reported that meals were interrupted due to their appliances. This result is consistent with Jaber et al.'s finding that patients with FA report eating difficulties as the most significant issue during their treatment.[14] Such difficulty could be due to the contours of the brackets, irritation from "pokey" wires, or pressure from periodic adjustments that make it uncomfortable for patients to bite. On the other hand, aligner patients can simply remove their trays during eating.

At pre-treatment, the majority of participants in both study groups had mild to moderate malocclusions. This is unsurprising, as aligner treatment is mainly prescribed for non-extraction cases with mild to moderate malocclusions, and the participants in the FA group were matched to the participants in the aligner group. The 2 groups were similar in all baseline parameters that we assessed. In particular, pre-treatment oral hygiene, ethnicity, and insurance coverage were similar, helping to minimize any bias from these factors. The data on the participant's non-adherence to inter-arch elastics and missed appointments were also collected for supplemental compliance assessment, which showed no significant differences between the groups. While this study was not randomized, the similarities in the characteristics between the groups was one of the strengths of this study.

Limitations:

The results of this study should be interpreted in the context of several potential limitations. First, there can be inherent biases associated with retrospective studies. To mitigate selection bias, participants were consecutively

recruited based only on the recency of treatment completion and the inclusion/exclusion criteria. Second, we did not include participants who switched treatment types which may affect the study outcomes. However, there were only three such participants being excluded from the study due to this reason. Third, the PAR index, which was used to measure treatment outcomes, is not as precise of an assessment tool as the ABO-OGS criteria. However, multiple previous studies have used this index to assess overall treatment outcome. Fourth, chart notes may under-report for data such as de-bonded appliances. However, this under-reporting would not be expected to be different between the two groups. Fifth, assessment of WSLs from photographic images may be complicated by potential reflections from the camera flash. This is why all subjects thought to have new/larger WSL were confirmed with a panel. Sixth, not all participants included in the chart review procedure for this study could be contacted for the administration of OHIP-14 questionnaire. Seventh, although the OHIP-14 questionnaire has been widely used in dental research, it has not been used to evaluate OHRQOL in adolescent orthodontic patients (and no existing instrument has). Lastly, about one-third of the participants in each group were in treatment during some period of the COVID-19 pandemic. When the pandemic began, office visits in our clinic were suspended for three months. Participants in the FA group may have been affected more compared to those in the aligner group, as they were unable to brush with their wires removed during that time.

CONCLUSIONS

1. Adolescent patients with mild to moderate malocclusions treated with either aligners or FA had similar occlusal outcomes as assessed by the PAR index.
2. Aligner patients developed fewer WSLs on the maxillary incisors compared to FA patients, and these lesions in the aligner patients were significantly smaller in surface area than in the FA patients.
3. Though total treatment times were similar in both groups, aligner patients had fewer scheduled visits, emergency visits, and de-bonded appliances compared to FA patients.
4. Although the overall OHRQOL was not different between the groups, significantly fewer aligner patients reported interruption of meals due to their appliances compared to FA patients.

Registration:

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APPENDIX 1

Modified OHIP-14 Questionnaire

Please circle your response for each question, using this scale:
0 = Never 1 = Seldom 2 = Sometimes 3 = Often 4 = Always

1. Have you had trouble pronouncing any words because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

2. Have you felt that your sense of taste has worsened because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

3. Have you had painful aching in your mouth during orthodontic treatment?

   0 1 2 3 4

4. Have you found it uncomfortable to eat any foods because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

5. Have you been self-conscious because of your teeth or mouth during orthodontic treatment?
   0 1 2 3 4

6. Have you felt tense because of problems with your teeth or mouth during orthodontic treatment?
   0 1 2 3 4

7. Has your diet been unsatisfactory because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

8. Have you had to interrupt meals because of problems with your teeth or mouth during orthodontic treatment?
   0 1 2 3 4

9. Have you found it difficult to relax because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

10. Have you been a bit embarrassed because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

11. Have you been a bit irritable with other people because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

12. Have you had difficulty doing your usual work because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

13. Have you felt that life in general was less satisfying because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

14. Have you been totally unable to function because of problems with your teeth or mouth during orthodontic treatment? 0 1 2 3 4

APPENDIX 2

Data Abstraction Form – Aligners Group

Patient Initials	Gender	Age	Racial and Ethnic Category	Disability	Insurance Coverage	Treatment Plan	Pre-Treatment PAR Score	Pre-Treatment Upper Arch Length	Pre-Treatment Lower Arch Length

Pre-Treatment Oral Hygiene	Oral Hygiene Counselling (%)	Emergency Visits	Number of De-bonded Attachments/Auxiliaries/Brackets	Other Complications	A-P Molar Classification	Overjet (mm)	Overbite (mm)	Crossbite	Mandibular Plane Angle (Sn/MnP)	Mandibular Plane Angle (FH/Me-Go)	Total Treatment Time (Months)

Data Abstraction Form – Fixed Appliances Group

Patient Initials	Gender	Age	Racial and Ethnic Category	Disability	Insurance Coverage	Treatment Plan	Pre-Treatment PAR Score	Pre-Treatment Upper Arch Length	Pre-Treatment Lower Arch Length

Pre-Treatment Oral Hygiene	Oral Hygiene Counselling (%)	Emergency Visits	Number of De-bonded Brackets/Bands	Other Complications	A-P Molar Classification	Overjet (mm)	Overbite (mm)	Crossbite	Mandibular Plane Angle (SN/MnP)	Mandibular Plane Angle (FH/Me-Go)	Total Treatment Time (Months)