

Evaluation of the dentoalveolar changes following extraction-based orthodontic treatment in patients with severe crowding using clear aligners in comparison with traditional fixed appliances: A randomized controlled clinical trial

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Keywords:

orthodontics, clear aligners, fixed appliances, dentoalveolar changes, severe crowding, four premolar extraction.

ABSTRACT

This study aimed to compare the dentoalveolar changes following the orthodontic treatment with clear aligners in comparison with the traditional fixed appliances. A single-center, 2-arm parallel-group RCT was conducted. Thirty-six adult patients (20 females, 16 males) who had severe crowding and required first-premolar extraction were recruited and allocated to the clear aligners group (CA), or the fixed appliances group (FA). Pre-and post-treatment dental cast models were evaluated by measuring the intercanine, interpremolar, and intermolar widths, arch length, and arch depth. Wilcoxon signed-ranks tests were used for intra-group comparisons, whereas Mann-Whitney U tests were used for inter-group comparisons. Bonferroni's adjustment of the alpha level was adopted. In the CA group, there were no significant differences in the maxillary and mandibular intercanine and interpremolar widths, whereas there were significant differences in the mandibular interpremolar width, maxillary and mandibular arch length, and depth ($P \leq 0.001$). In the FA group, there was a minor decrease in the transverse maxillary and mandibular arch widths with no significant differences. There was a significant decrease after treatment with the fixed appliances for the arch length and depth. There were no significant differences in the transverse arch widths, arch lengths, and arch depths ($P > 0.005$) between the two groups. The orthodontic treatment with four first-premolar extractions of severe crowding patients by the clear aligners or the fixed appliances is accompanied by slight and insignificant transverse changes on the arches, except for the interpremolar width in the lower premolar area in the CA group.



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1. Introduction

Orthodontic treatment has been a popular method for correcting misaligned teeth and achieving a more

aesthetically pleasing smile [1]. Traditional orthodontic treatment has relied on the use of fixed appliances, such as braces, to correct the malocclusion. However, clear aligners have recently gained popularity as an alternative to traditional appliances [2]. Clear aligners offer several advantages over conventional braces, including improved aesthetics, greater comfort, and the ability to remove them for eating and cleaning [3], [4]. Despite these benefits, orthodontists still debate the effectiveness of clear aligners compared to traditional braces [5].

Preserving the original shape of the dental arch, especially the lower intercanine width during orthodontic treatment, is one of the important issues that might be considered to maintain treatment results and reduce relapse during treatment planning [6]. orthodontic treatment with four premolars extraction is accused of negatively affecting the patient's smile after treatment by reducing the length and width of the dental arch, which leads to the appearance of black triangles in the corners of the mouth while smiling as a result [7]. Therefore, it has become necessary when studying any new treatment technique to compare the changes it makes to the dimensions of the dental arch. The aim of the present study was to compare the dentoalveolar changes of the orthodontic treatment with clear aligners in comparison with the treatment with fixed appliances, particularly the transverse widths, dental arch length, and depth.

2. Materials & Methods

2.1 Trial design, registration, and ethical approval

This study was a single-center, 2-arm parallel-group RCT. It was conducted at the Department of Orthodontics, University of Damascus Dental School, Damascus, Syria. The protocol of this study was reviewed and approved by the Ethics committee of the University of Damascus Dental School (Approval no. UDDS-6548-2019PG/SRC3903) and was funded by the University of Damascus Dental School Post-graduate Research Budget (Ref no. 871872250DEN). No changes in the study protocol have occurred after trial commencement. This study was reported according to the guidelines of CONSORT statement [8].

2.2 Participants, eligibility criteria, and setting

Thirty-six adult patients (20 females, 16 males) who had severe crowding and required orthodontic treatment with first premolars extraction were recruited from the Department of Orthodontics, University of Damascus Dental School, Damascus, Syria, from April 2019 to February 2020. The patients were randomly assigned to the Clear aligners (CA) group and fixed appliances (FA) group with a 1:1 allocation ratio. All the patients fulfilled the following criteria: (1) Age ranged from 18 to 25 years, (2) Class I malocclusion with severe crowding (more than 5 mm of tooth size-arch length discrepancy), (3) No congenitally missing or extracted teeth (except for the third molars), (4) No history of previous trauma to the maxillofacial region or surgical interventions. Patients with the following criteria were excluded: (1) Previous orthodontic treatment, (2) patients with psychological abnormalities, (3) patients with systematic diseases, and (4) patients who have known allergies to latex and plastic. Information sheets were distributed to all patients, and informed consent forms were collected. The first premolars were extracted in both groups one week before starting the active orthodontic treatment. No changes in the methods were made following trial registration. The CONSORT flow diagram of the recruited patients is illustrated in Figure 1.

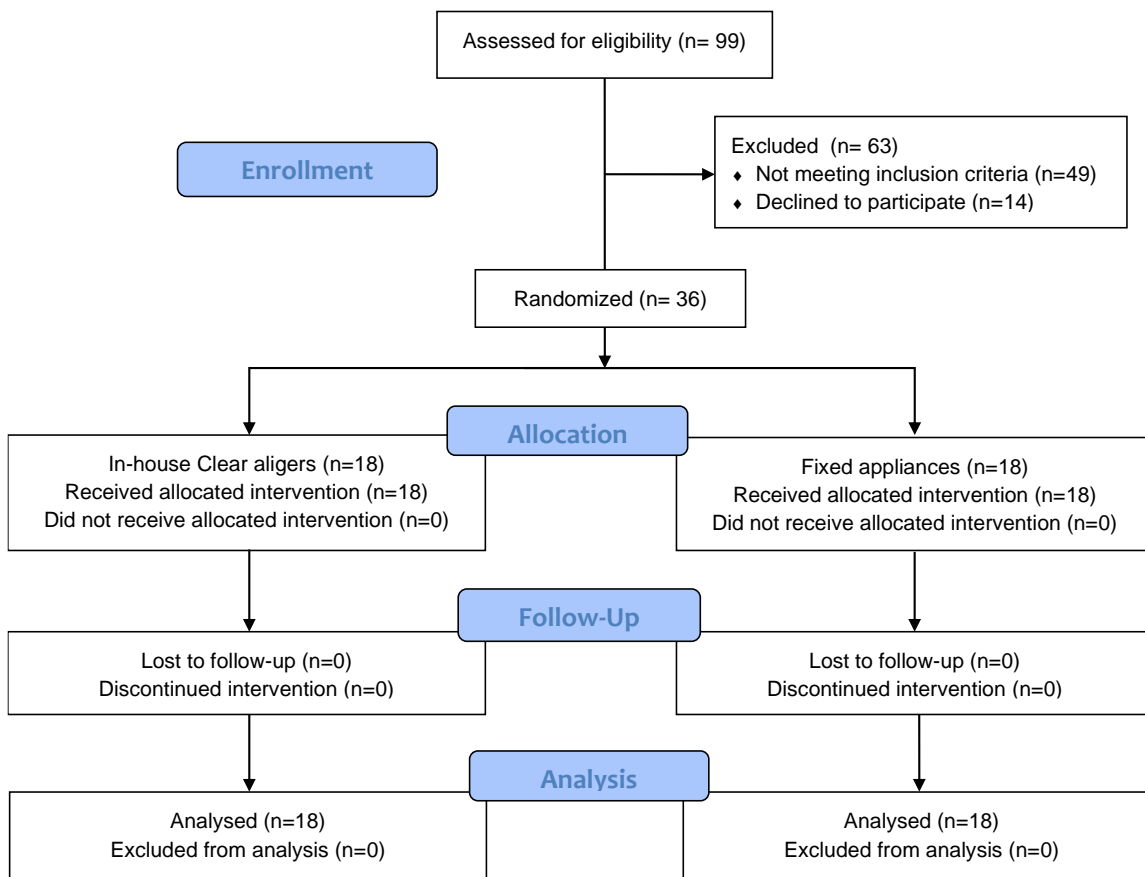


Figure 1: CONSORT flow diagram

2.3 Randomization and blinding

One of the academic staff not involved in this research project performed randomization. A computer-generated list of random numbers was exported by Minitab (version 17, Minitab, LLC, State College, Pa) with an allocation ratio of 1:1. Allocation sequence was concealed using sequentially numbered, opaque, sealed envelopes which were opened only after the completion of premolars extraction. Patients were sequentially allocated to the treatments in the order in which they were recruited. Blinding personnel and participants was impossible; blinding was only confined to the outcome assessor.

2.4 Clear Aligners (CA) Group

Treatment was conducted by one single trained examiner (S.T.J), and parameters were recorded by the same investigator. The virtual setup was prepared using Orthoanalyzer™ software (3Shape, Copenhagen, Denmark). After the first premolars were removed, proper alignment of the case was done, then the attachments were added; after that, the treatment plan was subdivided into subsets considering the maximum transitional movement and rotation for each tooth per aligner was 0.25 mm and 3 degrees, respectively. Virtual models were exported using the same 3shape software, printed using 3D validated printer (Moonray; Sprintray, Los Angeles, CA) [9], and clear aligners were fabricated for each model using the 0.762 mm Taguls™ premium (Taguls, Vedia solutions, Mumbai, India) aligner sheets and the Biostar® (Biostar, Scheu-dental, Iserlohn, Germany) thermoforming device. Each aligner was trimmed at the cervical margin of each tooth, polished, disinfected, and packed, then delivered to the patients. During the first appointment of aligners application, the attachments were bonded, and the patients were instructed how to use the aligners and to wear them 20-22 hours, seven days a week. Both groups used no buttons, interarch

elastics, or additional auxiliaries during the observation period. Each aligner was changed every 2 weeks. Malocclusion was corrected with no over-correction introduced. Refinement aligners were provided if needed. Each patient was seen every 4-8 weeks (2-4 aligners) to check for aligners fit, attachments stability, and cooperation.

2.5 Conventional fixed appliance (FA) group

The same examiner applied conventional orthodontic treatment with fixed buccal appliances to patients in this group (S.T.J). Fixed appliances were bonded one-week following first-premolars extraction. An MBT prescription brackets with a 0.022-in. slot height (Master Series®, American Orthodontics™, Sheboygan, WI USA) and anchorage devices (transpalatal arch with a Nance button) were used. The archwire sequence used was: 0.014-inch NiTi, 0.016-inch, 0.016 X 0.022-inch, 0.017 X 0.025-inch NiTi, and finally 0.019 X 0.025-inch stainless steel wire [10]. The patients in this group were seen every 3-4 weeks to monitor the treatment process and make the required activations and modifications during treatment. Archwires were replaced when crowding started to decrease, and the insertion of the following archwire appeared to be possible without applying excessive force on the engaged teeth. The treatment was considered finished when complete alignment of the teeth was done, extraction spaces were completely closed, and the American Board of Orthodontics (ABO) guidelines were achieved.

2.6 Outcome measure:

All the measurements included in this study were made by a calibrated examiner (the second author), who was blinded to the treatment group he was scoring. All the measurements were made on the pre-and post-treatment dental cast models. The following measurements were made on maxillary and mandibular dental casts: Intercanine width: distance between the tips of the cusps of the maxillary and mandibular canines; interpremolar width: distance between the central fossa on the occlusal surface of maxillary and mandibular second molars; Intermolar width: distance between the mesial fossa on the occlusal surface of the maxillary and mandibular first molars; arch length: distance from the mesial anatomical contact point of the permanent first molar to the point of contact of the central incisors (or the middle point between them in the event of space) which is calculated for the right and left sides, then divided by 2, and arch depth: distance from a point midway between the facial surfaces of the central incisors to a line tangent to the mesial surfaces of the first permanent molars [11], [12].

2.7 Statistical analysis:

Statistical analysis was performed using the SPSS (version 25.0; IBM, Armonk, NY, USA). Anderson-Darling Normality tests were used to test the normality of distributions. Wilcoxon Signed Ranks tests were used to test for significant differences in each of the studied groups, whereas Mann-Whitney U tests were used for significant differences between the two groups. Because of multiple comparisons, Bonferroni correction was applied, and the adjusted alpha level was set at 0.005.

3. Results

3.1 Clear aligners group (Table 1):

There were no significant differences in the maxillary and mandibular intercanine, and interpremolar widths ($P>0.005$) after orthodontic treatment with clear aligners. In contrast, there were significant differences in the mandibular interpremolar width, maxillary and mandibular arch length, and depth ($P\leq 0.001$).

Measurements‡	T0				TF				T0 vs. TF	
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	P-value†

											difference	
Intercanine width	Maxillary	34.81	1.79	31.64	39.93	34.86	2.08	32.16	40.21	0.04	0.555	
	Mandibular	26.13	1.99	21.21	28.65	27.12	1.95	25.34	30.49	0.99	0.213	
Interpremolar width	Maxillary	43.04	2.43	38.07	47.90	42.35	2.42	39.84	48.21	0.69-	0.380	
	Mandibular	36.35	2.61	33.89	41.78	34.62	2.82	31.73	39.71	1.72-	*0.001>	
Intermolar width	Maxillary	47.47	3.18	43.64	53.51	47.83	3.04	44.51	54.13	0.36	0.182	
	Mandibular	40.16	4.29	35.14	48.05	40.75	3.34	37.25	48.39	0.60	0.121	
Arch length	Maxillary	32.96	2.07	29.56	35.98	29.14	1.63	26.93	31.67	3.82-	*0.001>	
	Mandibular	27.14	1.92	24.50	29.77	24.73	1.19	23.27	26.69	2.41-	*0.001>	
Arch depth	Maxillary	24.97	3.06	19.10	30.00	22.01	2.04	19.50	26.00	2.96-	*0.001	
	Mandibular	20.99	1.18	18.50	23.50	18.30	0.75	17.50	20.00	2.69-	*0.001>	

T0: before treatment, TF: after treatment, CA: clear aligners.
† Employing Wilcoxon Signed Ranks tests. *Bonferroni's correction was used to adjust the level of significance to 0.005.
‡ Measurements in mm.

3.2 Fixed appliances group (Table 2):

In the FA group, there was a minor decrease in the transverse maxillary and mandibular arch widths with no significant differences ($P>0.005$). There were significant decrease ($P<0.001$) after treatment with the fixed appliances for the arch length and depth, with mean differences of 3.80 and 2.49 mm for the maxillary and mandibular arch lengths, respectively. Meanwhile, the mean differences for the maxillary and mandibular arch depth were 3.38, and 3.89 mm, respectively.

Table 2: Descriptive statistics of the outcome measurements in the FA group (n=18) and the result of the significant tests

Measurements‡		T0				TF				T0 vs. TF	
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean difference	P-value†
Intercanine width	Maxillary	35.49	3.09	30.37	41.78	34.37	1.97	30.69	38.48	1.12-	0.098
	Mandibular	26.03	2.91	22.01	34.35	26.75	2.17	23.69	33.50	0.72	0.338
Interpremolar width	Maxillary	43.40	2.08	39.94	47.09	43.02	1.74	39.61	46.28	0.37-	0.695
	Mandibular	36.47	4.63	20.21	41.62	36.24	2.04	32.89	42.08	0.23-	0.145
Intermolar width	Maxillary	49.19	2.19	45.22	51.98	47.94	1.59	44.66	50.32	1.24-	0.020
	Mandibular	42.17	3.66	30.04	46.98	41.32	1.58	38.49	45.57	0.84-	0.085
Arch length	Maxillary	33.35	2.19	29.75	37.27	29.55	1.53	26.60	32.47	3.80-	*0.001>
	Mandibular	27.85	1.89	24.96	31.76	25.36	1.58	23.16	29.20	2.49-	*0.001>
Arch depth	Maxillary	25.66	3.10	19.10	30.00	22.27	1.76	19.00	25.50	3.38-	*0.001
	Mandibular	21.45	1.70	16.80	23.50	17.56	4.12	14.90	22.00	3.89-	*0.001

T0: before treatment, TF: after treatment, FA: Fixed appliances.
† Employing Wilcoxon Signed Ranks tests. *Bonferroni's correction was used to adjust the level of significance to 0.005.
‡ Measurements in mm.

3.3 Clear aligners vs. Fixed appliances (Table 3):

When comparing the outcome measurements changes between the studied groups, the study revealed that there were no significant differences in the transverse arch widths, arch lengths, and arch depths ($P>0.005$).

Table 3: Descriptive statistics of the changes of the outcome measurements after treatment and the result of the significant tests

Measurements‡		CA group (n=18)				FA group (n=18)				CA vs FA	
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean difference	P-value†
Intercanine width	Maxillary	0.04	1.98	-5.71	2.72	1.12-	2.83	-3.57	7.71	-1.17	0.159
	Mandibular	0.99	2.79	-5.06	2.41	0.72	2.45	-5.33	2.53	-0.26	0.761
Interpremolar width	Maxillary	0.69-	2.27	-5.02	3.45	0.37-	1.83	-1.70	4.91	0.31	0.651
	Mandibular	1.72-	0.72	0.02	2.33	0.23-	4.34	-15.01	6.55	1.50	0.166
Intermolar width	Maxillary	0.36	1.27	-2.41	2.25	1.24-	2.06	-3.69	5.02	-1.60	0.009
	Mandibular	0.60	1.66	-2.41	2.59	0.84-	3.35	-8.89	8.49	-1.44	0.114
Arch length	Maxillary	3.82-	0.78	1.67	4.87	3.80-	1.92	0.49	7.10	0.01	0.976
	Mandibular	2.41-	1.03	1.23	4.68	2.49-	1.62	-0.34	6.70	-0.08	0.853
Arch depth	Maxillary	2.96-	2.24	-1.90	6.60	3.38-	2.94	-3.00	7.20	-0.42	0.629
	Mandibular	2.69-	1.10	0.00	4.10	3.89-	2.08	-2.10	7.20	-0.19	0.726

CA: Clear aligners, FA: Fixed appliances.
† Employing Mann-Whitney U tests. *Bonferroni's correction was used to adjust the level of significance to 0.005.
‡ Measurements in mm.

4. Discussion

When the published medical literature was reviewed, no studies were found to evaluate the changes in the dimensions of the dental arches after treatment of extraction-based malocclusion cases with clear aligners. Therefore, the results of this study were compared with studies that included different types of malocclusion treated with clear aligners, whether that included a comparison with fixed appliances or not. Orthodontic treatment with premolars extraction has led to a significant decrease in the length of the upper and lower dental arches, with an average of 3.82 and 2.41 mm in the aligners group and 3.80 and 2.49 mm in the fixed appliances group, respectively. The treatment also led to a decrease in the depth of the upper and lower dental arches, with an average of 2.96 and 2.69 mm in the aligners group and 3.38 and 3.89 mm in the fixed appliances group, respectively. This might be related to the alignment of the incisors and the correction of their axes, which were characterized mainly by a slight labial proclination before treatment, in addition to the incisor's retraction and mesial movements of the posterior teeth in some cases that required this.

Treatment with clear aligners has significantly decreased the interpremolar width with an average of 1.72 mm. At the same time, the changes in the rest of the studied transverse measurements were minor and statistically insignificant. No significant changes in the transverse measurements of the maxillary and mandibular arches were recorded in the fixed appliances group. The results of this study differ from those of [13] which showed an increase in the transverse measurements and the depth of the maxillary dental arch after treating cases of mild crowding with clear aligners from Invisalign®. It also differs from those of [14], [15], which showed a significant increase in the transverse measurements of the upper dental arch after treatment with clear aligners from Invisalign®, and this might be attributed to the difference in the nature of the treated cases and the method of treatment, as the two studies included cases of mild to moderate crowding without extraction. In contrast, the current study included patients with severe crowding that required the extraction of the first four premolars. The results of this study differed from the results of [16] study, which showed a significant increase in width between the lower canine after treatment by removing the first four premolars and using fixed orthotics. This difference can be attributed to the fact that the current study included cases of class I malocclusion with severe dental crowding. In contrast, the study of [16] relied on cases of class I malocclusion that required the extraction of the first four premolars, which may include cases of bimaxillary protrusion accompanied by a greater retraction than the treated cases in this study and thus associated with a greater increase in width between the lower canines.

The study showed that there were no significant differences between the two studied techniques when comparing the changes in the dimensions of the dental arches after treatment. Treatment with fixed appliances led to a decrease in the upper intercanine, upper intermolar, lower intermolar widths, while these widths increased slightly during the treatment with clear aligners, which indicates that clear aligners maintains the aforementioned arch widths without significant change. As for the length and depth of the upper and lower dental arches decreased by similar amounts in both techniques. The results of this study differ from that of [13] which found that the treatment with the self-ligating brackets increased the transverse measurements of the dental arch more than the increase associated with the treatment with clear aligners, and this difference with current study could be attributed to the different nature of the treated cases and the aligners system used in the two studies and the difference in fixed appliances technique used in the two studies. The results of this study are consistent with [17] which showed that there were no significant differences in the intercanine width after treatment with clear aligners for Class I malocclusions without extraction in comparison to the pre-adjusted fixed appliances.

5. Conclusions

The orthodontic treatment with four first premolars extraction of severe crowding patients by the clear

aligners or the fixed appliances is accompanied by slight and insignificant transverse changes on the arches, except for the interpremolar width lower premolar when using clear aligners, which shows a significant decrease. It is also associated with a significant decrease in the length and depth of the dental arch, regardless of the treatment technique used.

6. References

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