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Comparison of Maxillary Expansion Between Clear Aligners and Removable Expansion Appliance in the Mixed Dentition

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by

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ABSTRACT

Background: Orthodontic and orthopedic expansion is necessary to create space to resolve crowding due to arch deficiency or tooth size discrepancy. The Invisalign First clear aligner appliance as a modality for early interceptive orthodontic treatment has become incorporated into orthodontic practices in very recent years. The present study aims to investigate the magnitude of expansion of the Invisalign First clear aligner appliance compared to a Schwartz removable expander in patients with mixed dentition. Additionally, the study aims to compare the efficacy and predictability of Invisalign First clear aligners in this population.

Materials & Methods: In this retrospective study, a sample was collected from a single orthodontist practitioner. The sample consisted of 34 patients, 16 patients treated with Invisalign First clear aligners only (Group1) and 19 patients treated with a Schwartz removable appliance and Invisalign First clear aligners (Group 2). Intraoral scans of four timepoints, initial (T1), post-expansion for Group 2 only (T1Exp), first refinement (T2), and final (T3), and planned Clincheck goal (P) model from Clincheck software were imported to Align Technology's digital measure program (Quantify©). Arch widths and molar inclinations were measured at each timepoint and the changes between timepoints were calculated. Predictability of arch expansion was calculated as T13 (change between initial and final) divided by the Planned dimension multiplied by one hundred. A two sample t-test was used to assess differences in the changes in arch widths and predictability of expansion between two groups.

Results: There were statistically significant differences found in the magnitude of expansion and predictability of arch expansion between two groups. Group 2 showed a greater amount of expansion and predictability. Group 1 showed about 50-60% of the planned expansion at the end of treatment. In regards to magnitude of expansion when comparing the two groups, the efficacy predictability of transverse dimensional changes were significantly greater in the Group 2 compared to Group 1, 83% vs 56% (p = 0.001), respectively. The changes in inclination were similar in both groups, with no statistically significant differences.

Conclusions: There is a significantly greater amount of expansion and greater predictability with the Schwartz removable appliance compared to the Invisalign First clear aligner appliance in the mixed dentition. The predictability of Invisalign First was 56% and indicates a significant overcorrection of arch expansion is required at the virtual treatment planning stage in Clincheck in order to obtain the arch expansion that was planned

INTRODUCTION

There is controversial opinion regarding treating patients in the mixed dentition phase compared to waiting until all permanent teeth have erupted for comprehensive phase of orthodontic treatment. There is support in the literature for the ideal time to start treatment, but no absolute conclusion has been reached. One of the main goals of Phase I orthodontic treatment is usually to correct a transverse discrepancy prior to the complete fusion of the palatal suture and to promote normal craniofacial growth. Currently there are numerous appliances available for skeletal and/or dental expansion and it is important to understand the capabilities and limitations of each before treating patients.

Orthodontic expansion is necessary to create space to resolve crowding due to arch deficiency or tooth size discrepancy. Expansion can also be used to achieve smile broadening esthetics[1]. A commonly associated characteristic in maxillary dental arch constriction in mixed or early dentitions is unilateral or bilateral crossbite. The prevalence of a posterior crossbite ranges from 8-16% in the primary and early mixed dentitions, with a predominance of unilateral crossbites.[2] There is usually no self-correction of transverse malocclusions during craniofacial growth. To alleviate a transverse deficiency, either slow (SME) or rapid (RME) maxillary expansion can be used to achieve an increase the width of the maxillary dental arch. Expansion should be completed as early as possible as the maxillary suture fusion is not complete and the maxillary and mandibular alveolar processes are still developing. In general, as a person ages, there are lesser dental effects and skeletal changes that are possible. Crossbites may even worsen with growth and affect maxillary growth and function.[2] Therefore, early correction of crossbites in the posterior through maxillary expansion may result in better eruption position of the permanent teeth, eliminate premature occlusal contacts, and to improve dentoskeletal relationships during periods of growth (2, 3). Transverse deficiency can be categorized as skeletal and/or dentoalveolar in origin. It is important to determine the etiology of the discrepancy to treat adequately.

Due to the midpalatal suture, skeletal expansion is possible in the maxilla, in addition to dental expansion. Expansion is accomplished with orthopedic and/or orthodontic effect. As transverse forces are applied, depending on the age and gender of the patient and type of appliance, tooth movement may be more bodily and/or tipping (i.e. inclination) to various degrees (3). It is important to understand there is a natural increase in the transverse width prior to the palatine suture completely fusing. There is a greater increase of permanent intermolar width in correspondence with the growth in the median suture compared to the smaller increase at the intercanine width. It was measured that there is an average increase of 1-3 mm in intercanine width and 6-9 mm for intermolar width from the age of 4 to adulthood (3).

Orthodontic tooth movement with Invisalign constitutes a programmed sequence of plastic aligners that move the dentition in small increments. The clear aligners are removable, made of 0.75 mm thick polyurethane, and cover the entire surfaces of the upper and lower teeth. Each aligner produces a precise programmed movement of 0.15-0.25 mm per tooth. Previous research has displayed that dental arch expansion is possible and predictable with Invisalign (1). Although there are differences between braces and Invisalign, the treatment goal is typically the same and the use of certain appliances is still possible with Invisalign.

Currently, there is limited literature surrounding the predictability and level of expansion that is achievable using Invisalign. Studies that have been published on Invisalign generally have subjects that are non-growing adults and have full permanent dentition. In a study of adult patients, transverse changes examined identified landmarks on study models to quantify Clincheck predictability. The study examined the correlation between the amount of programed expansion and the initial molar torque, efficacy, and efficiency of bodily expansion. It was observed that the greater transverse changes were at the cusp tips and less at the gingival margin, the greatest accuracy at the canine tips, and less expansion was achieved in the posterior. The possible reasons stated for the results observed included differences in root anatomy, cortical plate thickness, higher mastication loading, and greater soft tissue resistance from the cheeks. The study also determined that if there was greater expansion planned in the Clincheck it was not associated with less accuracy. It was also observed that the Clincheck had more bodily movement programmed than the dental tipping that was observed in the treatment outcomes. In the conclusion, they cautioned that the normal growth may be responsible for some changes in the growing population (4).

Although clear aligner therapy has been utilized for several years, the studies examining the efficacy and efficiency in maxillary and mandibular expansion are more limited. However, the predictability and clinical outcomes have been examined. A study conducted to evaluate the efficiency of maxillary expansion with clear aligners (Invisalign©) and analyze the possible influencing factors examined 3D models pre and post-treatment. Upper dental arch width, buccal inclination of posterior teeth and the expansion efficiency (expansion acquired/expansion planned) was measured. It was observed that the posterior teeth showed significantly more buccal inclination compared the programmed position. The most buccally inclined tooth observed were the first molars. The results also demonstrated that the expansion efficiency was of premolars with a 2 mm intermolar increase was greater than when planned for more than 2 mm. They determined from their results that there was no significant effect on the expansion efficiency from the planned buccal inclination, attachments, and the expansion mode. They concluded that the expansion of the maxillary arch with clear aligners was achieved by the buccal movement of the posterior teeth with more limited buccal inclination. They also determined that there was a decrease in the efficiency of expansion from 1st premolars to second molars. In addition, the intermolar width planned initially had a significant influence on the efficiency of premolar expansion (5).

There has been much debate surrounding the control of tooth movement with clear aligners. A systematic review was conducted to assess the evidence related to the efficacy of clear aligner treatment in controlling orthodontic tooth movement. They identified that upper molar bodily movement of approximately 1.5 mm was effectively controlled (6). A study investigating the efficiency and pattern of movement of upper arch expansion using Invisalign clear aligners that evaluated the association between the amount of programmed expansion and the efficiency of bodily expansion, in addition to molar torque and efficiency of bodily expansion. It has been determined that aligners could increase arch width, but expansion may be achieved by tipping movement in adults (4). A study was carried out to validate a new method for quantifying the predictability of planned expansive movement with the Invisalign system. In addition, they aimed to determine whether there are statistically significant differences between planned expansion in the Clincheck and actual clinical measurements by comparing maxillary post-treatment models. The differences between the 3D model and ClinCheck at the second timepoint showed that planned expansion at the end of treatment is not predictable. (7). On the other hand, another study also investigating the predictability of arch expansion using Invisalign determined that there was a degree of predictability. The pre and post-treatment digital models of adult patients were examined and the average accuracy of expansion planned with Invisalign for the maxilla was 72.8%, while an overall accuracy of 87.7% was measured in the mandibular arch. They concluded that the Clincheck does overestimate bodily expansive movement and that there is more tipping in the adult dentition. They recommended overcorrection of expansion when planning buccal movements (1).

Invisalign First clear aligners are a new technology aimed at treating a range of malocclusions in the mixed dentition. This provides another appliance for orthodontic practitioners to consider once they have completed their diagnosis. This technology was released in 2018 and limited literature exists on its efficacy and predictability. At this time only case reports have been documented. There is very limited published literature evaluating Invisalign First in the mixed dentition and at this time only case reports have been published. One case report examined space management in the mixed dentition and determined that expansion is important and may be accomplished with clear aligner therapy for small tooth movement. In addition, they discussed the possible treatment effects that include resolving crowding, closing spaces, arch expansion or constriction, space maintenance or increase, intrusions or extrusion, eruption guidance and other interceptive orthodontic treatment (8). Another case report describing several cases with treatment objectives of dentoalveolar expansion and arch development, and alleviating crowding was completed (9). Further studies are necessary to examine the efficacy, predictability, and efficiency of clear aligner therapy in the mixed dentition. The evaluation arch development, dentoalveolar expansion, and growth modification in short and long-term are important to better understand this treatment modality and the potential significance in treatment outcomes. Studies that evaluate its abilities to correct various malocclusions and how it compares to other appliances are vital to a clinician's decision in treatment planning. The importance of adequate diagnosis followed by selecting the most appropriate form of treatment involves understanding the capabilities and limitations of appliances.

The objectives of this study were to evaluate the magnitude of expansion of Invisalign First clear aligners compared to the Schwartz removable expander in the mixed dentition and to evaluate the efficacy and predictability of Invisalign First clear aligners in the mixed dentition. The null hypothesis was that there is no difference in the magnitude of expansion between the Schwartz removable expander and Invisalign First clear aligner appliance in the mixed dentition. The secondary questions were posed to determine what the efficacy and predictability of Invisalign First clear aligners is and if there was a difference in the inclination in the Schwartz removable expander group compared to the Invisalign First clear aligner group.

MATERIALS & METHODS

The sample was drawn retrospectively from the practice of a single clinician who is considered an expert in clear aligner therapy and highly experienced in the mixed dentition treatment approach using removable appliances. This study was approved by the Institutional Review Board of the the University of the Pacific School of Dentistry in 2021 (#20-51).

The patient population in this study were patients in the mixed dentition who underwent comprehensive Invisalign First clear aligner Phase I orthodontic treatment. The inclusion criteria included the following: patients who started and finished treatment between October 2018 through May 2021, patients who completed comprehensive Phase I Invisalign First clear aligner treatment with or without Schwartz removable expander in mixed dentition, all first permanent molars and primary molars present at initial timepoint, and all records for timepoints are available. The exclusion criteria included the following: inadequate digital models, patients had other types of orthopedic appliances (MA, Crozat, Herbst, Headgear, etc.), and planned expansion was less than 2 mm.

Two treatment groups were identified based on treatment type: 1) patients who received Invisalign First clear aligners only (Group 1), and 2) patients who received Schwartz removable expander appliance (Figure 1) followed by Invisalign First clear aligner treatment (Group 2). The Invisalign First clear aligners were delivered on the lower arch simultaneously with the Schwartz appliance delivery on the upper arch. Following the expansion and retention period of the Schwartz removable expander on the upper arch, a refinement scan was completed for the start of both upper and lower arch with Invisalign First clear aligners.

The total number of patients who started and completed Invisalign First clear aligners comprehensive package was 85 patients. Of these, 18 patients had Invisalign First clear aligners only. From this group of 18, two patients were removed as the programmed expansion was less than 2 mm. This left a total of 16 patients who underwent Invisalign First clear aligner comprehensive treatment only. There were 53 patients who completed treatment with a Schwartz removable expander and Invisalign First clear aligner treatment. From these 19 were randomly selected for comparison. The remaining 14 patients had undergone Invisalign First clear aligner therapy and a different orthopedic appliance. The sample size was calculation was calculated for the effect to sample size ratio to equal one. A sample size of 16 is adequate for providing an alpha of 0.05 and minimum power of 80%.

The Schwartz maxillary removable expander appliance with occlusal coverage was utilized with the same design and protocol for all patients in this practice. The protocol was as follows: adjust the screw ¼ turn 2x/week and if progress is poor, up to 3x/week or every day. With this appliance expansion can be completed and held for 8-12 months.

Each group had set time points for data gathering and analysis. For the Invisalign First clear aligner group, these included: T1 (initial Invisalign First), T2 (first refinement), T3 (final scan), and P (Clincheck goal). For the Invisalign First clear aligner and Schwartz removable expander group these included: T1 (initial Invisalign First), T1-Exp (expansion), T2 (Invisalign First), T3 (final scan), and P (Clincheck goal). Outcome variables included: arch dimensional measurements (U_66, U_EE, U_DD, U_CC), inclination measurements (UR6_Inc, UL6_Inc, URE_Inc, ULE_Inc, URD_Inc, ULD_Inc, URC_Inc, ULC_Inc), and predictability. Predictability was calculated as T13 (change between initial and final) divided by the Planned dimension multiplied by one hundred.

The measurement software was Align Technology's© Quantify software which utilizes superimposition capabilities after landmark identification. The software is programed to recognize permanent dentition and once data points were added for the primary dentition, superimposition of each timepoint could be completed for each case. This would provide a more accurate transverse dimensional analysis with the superimposition capabilities. The upper and lower arch measurements and changes for each case at each timepoint were run with the software program. This software accuracy has not been fully studied and it has limitations if a tooth is not fully erupted.

Statistical analysis

The Chi-square test was used to determine if there were statistically significant differences in sex and number of refinements. The Paired T-test was used to determine if there were statistically significant differences for arch dimensional changes between time points. The T-test was used to determine if there were statistically significant differences for comparison between two groups. Statistical analyses were performed using SAS software version 9.4 (SAS institute, Cary, NC, USA).

RESULTS

There were no statistically significant differences in the ages at the time of the start of treatment and at the time treatment was completed in both study groups. There was a statistically significant difference in T1 and T2, the initial to first refinement, as Group 2 had the removable expander period. This period, and additional time between T1 and T2 was 5.9 months on average. The overall treatment time length was similar (Table 1). The average age at the start of treatment for Group 1 was 8.8 years and 8.7 years for Group 2. The average age at the T2 for Group 1 was 9.4 and 9.9 for Group 2, the difference of which is the expansion period. The average age at T3 was 10.3 years and 10.1 for Group 2. There were no statistically significant differences in sex for both the study groups (Table 2). In Group 1 there were 6 males and 10 females and in Group 2 there were 7 males and 12 females. There was a statistically significant differences in the number of refinements for both study groups (Table 3). Significantly more refinements were completed in study Group 1. In Group 1, 75% (12 patients) had at least one refinement. In Group 2, 57% (8 patients) had at least one refinement. Overall, 15 total (43%) did not have a refinement, 25% of the Group 1 and 58% of Group 2.

There were no statistically significant differences in arch dimensions at the initial timepoint, T1 (Table 4). The transverse measurements for both groups were comparable to each other for the upper C, D, Es and 6s. There were no statistically significant differences in arch dimensions for the planned arch expansion, P (Table 5). The planned increase in transverse measurements for both groups were comparable to each other for the upper and lower C, D, Es and 6s. The expansion planned on the upper arch ranged from 3.4 mm to 5.9 mm depending on what the dentition was. The arch expansion differences from T1 to T2 were statistically significant for all the dentition. The greatest differences were observed on the upper Cs, Group 2 achieved even significantly greater expansion (4.2 mm) compared to Group 1 (1.7 mm). The majority of the expansion for Group 2 occurred during the period of time with the Schwartz removable expander (Table 7). For example, an average of 4.2 mm of expansion was achieved between the first upper molars during the time period with the Schwartz removable expander and then 0 mm on average with the Invisalign First clear aligners first set that followed. Overall, there was a minimum change in expansion during the aligner period.

The predictability of expansion was calculated as the change from T1 to T3 divided by the planned expansion. In Group 1, the average expansion predictability ranged from 42% at the primary canines, 63.3% at the primary first molar, 68.9% at the primary second molar, and 56.6% at the permanent first molar. It was observed that numerous primary teeth had exfoliated, more significantly so, in the Invisalign First clear aligner only group. In Group 2, the average expansion predictability ranged from 80.1% at the primary canines, 82% at the primary first molar, 88.4% at the primary second molar, and 82.3% at the permanent first molar (Table 8).

The predictability of expansion in the first set of aligners was further evaluated due to the significant exfoliation of primary teeth at the end of treatment. In Group 1, the average expansion predictability ranged from 53.6% at the primary canines, 58.8% at the primary first molar, 62.3% at the primary second molar, and 48.8% at the permanent first molar. In Group 2, the average expansion predictability ranged from 78.9% at the primary canines, 85% at the primary first molar, 89.3% at the primary second molar, and 79.3% at the permanent first molar (Table 9).

The inclination for Group 1 and 2 was similar in change for all of the upper dentition (Table 10). The expansion efficiency in regards to inclination was examined. There were no significant differences between T1 (Schwartz expansion) and T12 (Post-Schwartz Invisalign phase) (Table

11). Inclination is shown in the first half of the chart. The second shows no further expansion or uprighting with the clear aligner phase.

DISCUSSION

The null hypothesis was rejected. There is a statistically significant difference in the magnitude of expansion between Group 1 and Group 2 measurements of expansion in the mixed dentition. The efficacy of transverse dimensional changes was significantly greater in Group 2. Overall, this was 4.5 mm in Group 1 compared to 2.75 mm in Group 2 on average. It would likely be expected that more expansion would be achievable in the mixed dentition when observing the Invisalign First clear aligner appliance as the root length is shorter and the appliance is applying continuous light forces. The reasons for less expansion observed than expected may include the smaller clinical crown size, treatment time, and initial malocclusion. The predictability of transverse dimensional changes was significantly greater in Group 2. Overall, this was 83% mm in Group 1 compared to 56% mm in Group 2 on average. There were similar values of inclination that resulted for both groups. It would likely be expected that more inclination would be observed in the Schwartz removable expander group. This was not observed and is most likely due to the occlusal coverage which leads to less buccal tipping. Future comparison of different types of expanders would provide additional insight and comparison. The occlusal coverage can prevent significant buccal tipping through disengaging the bite and providing vertical control in addition to the molar axial inclination observed. Disengaging the occlusal forces allows expansion to be more efficiently accomplished. The Invisalign First clear aligner appliance utilizes this same principle of occlusal coverage, disengaging the occlusal forces.

The reason behind the increased rate of exfoliation in Group 1 are the attachments on the posterior teeth in combination with the regular removal and replacement of the aligners. There is also less expansion with the clear aligners in Group 2 because most of the expansion goal was achieved with the removable expander. The canines had significantly more expansion in Group 2 compared to Group 1. This could be due to the design of the Schwartz expander and efficacy of the expansion.

The Invisalign First clear aligners achieved 56% of what was planned overall. In a study published evaluating expansion in adults treated with Invisalign clear aligner therapy, the average expansion achieved in the maxilla was 72.8%. The planned expansion ranged from 2-4 mm, resulting in 0.2-1.1 mm less than the goal. In the lower arch the overall average expansion achieved was 87.7% of the goal expansion. The planned expansion was 1.5-3 mm, resulting in 0.07 – 0.65 less than the goal. It was concluded that the Clincheck overestimates the amount of bodily expansive transverse movement and that there is more tipping observed in the adult dentition (1). In another study examining inclination in the posterior dentition, it was observed that the teeth showed significantly more buccal inclination compared to the planned position, with the most buccally inclined tooth being the first molars (5).

There were several limitations of this study. There was no follow up to Phase II to determine if further expansion is needed. There were no radiographs included in the study, which would allow evaluation of skeletal expansion and vertical control. This was a new approach to evaluating these appliances with recently available software. There should be careful interpretation of the results as the data came from only one orthodontic practice.

There are several future studies that would be interesting for follow up of this study. It would be important to determine if arch width is maintained from Phase I treatment to Phase II start of treatment. Additionally, it would be important to determine the amount of dental versus skeletal expansion. In general, it would be important to include additional practitioners for generalizability of the results.

CONCLUSION

There are several important conclusions that can be formed from this study's results. There is a significant difference in the magnitude of transverse expansion between the Schwartz removable expander appliance and Invisalign First clear aligner appliance in the mixed dentition. There was less expansion achieved in the Invisalign First clear aligner appliance. The predictability was approximately half of the planned movement with Invisalign First clear aligners. This is a good reference for future studies on Invisalign appliances.

FIGURES

Figure 1. Schwartz removable expander appliance.

Figure 2.

TABLES

Table 1. Sample characteristics – age of study groups.

	Group 1 (n=16)		Group 2 (n=19)				
Variable	Mean	SD	Mean	SD	Mean Diff	SD	P*
Age_T1	8.8	0.9	8.7	0.9	0.12	0.89	0.7
Age_T1Exp	.	.	9.2	0.9			
ExpTime_Month	.	.	5.9	1.5			
Age_T2	9.4	0.8	9.9	0.9	-0.42	0.89	0.2
Age_T12	0.7	0.2	1.2	0.2	-0.54	0.20	<.0001
Age_T3	10.3	0.9	10.1	0.9	0.18	0.90	0.6
Age_T13	1.51	0.7	1.46	0.3	0.06	0.51	0.73
*, ttest							

Table 2. Sample characteristics – sex of both study groups.

	Sex				
	Male		Female		
Group	N	%	N	%	p*
Group 1	6	37.5	10	63	0.97
Group 2	7	36.8	12	63.1	
Total	13	37.14	22	62.86	
*, Chi-square test					

Table 3. Sample characteristics – number of refinements for both groups.

	Sex				
	Male		Female		
Group	N	%	N	%	p*
Group 1	6	37.5	10	63	0.97
Group 2	7	36.8	12	63.1	
Total	13	37.14	22	62.86	
*, Chi-square test					

Table 4. Arch dimension at initial timepoint, T1.

	Group 1			Group 2						
Variable	N	Mean	Std Dev	Variable	N	Mean	Std Dev	Diff	SD	P
U_66_T1	15	50.5	3.2	U_66_T1	19	49.7	2.6	0.8	2.87	0.42
U_EE_T1	16	44.1	2.8	U_EE_T1	18	43.6	2.2	0.59	2.47	0.49
U_DD_T1	16	39.3	2.7	U_DD_T1	18	38	1.8	1.25	2.27	0.12
U_CC_T1	16	33.3	2.1	U_CC_T1	19	32	2	1.32	2.07	0.7
L_66_T1	16	44.6	2.7	L_66_T1	19	44.2	2.4	0.4	2.55	0.65
L_EE_T1	16	40.4	2.5	L_EE_T1	19	40.5	2.5	-0.11	2.47	0.89
L_DD_T1	16	31.4	2.4	L_DD_T1	17	31.7	1.7	-0.28	2.08	0.7
L_CC_T1	12	25.5	2.1	L_CC_T1	15	25.8	1.8	-0.4	-1.93	0.6

Table 5. Planned arch expansion for both groups.

	Group 1			Group 2						
Variable	N	Mean	Std Dev	Variable	N	Mean	Std Dev	Diff	SD	P
U_66_P	15	5.1	1.1	U_66_P	19	5.4	2.2	-0.3	1.79	0.63
U_EE_P	16	5.9	1.2	U_EE_P	18	5.6	2.3	0.32	1.87	0.62
U_DD_P	16	5.2	1.2	U_DD_P	18	5.4	2	-0.21	1.66	0.72
U_CC_P	16	3.4	1.1	U_CC_P	18	5.2	1.5	-1.83	1.34	0.0004
L_66_P	16	4.9	0.9	L_66_P	18	4.9	2.3	-0.03	1.8	0.97
L_EE_P	16	5.5	0.9	L_EE_P	19	4.9	2.7	0.53	2.1	0.45
L_DD_P	16	4.8	1.2	L_DD_P	17	4.1	2.2	0.71	1.8	0.27
L_CC_P	12	2.4	1.2	L_CC_P	15	2.5	2.1	-0.07	1.74	0.92

Table 6. Arch expansion changes from T1 to T2.

	Group 1			Group 2						
Variable	N	Mean	Std Dev	Variable	N	Mean	Std Dev	Diff-Mean	SD	P
U_66_T12	15	2.5	1.4	U_66_T12	19	4.2	1.7	-1.74	1.53	0.003
U_EE_T12	14	3.7	1.5	U_EE_T12	16	5.1	2	-1.45	1.78	0.034
U_DD_T12	12	3.2	1.5	U_DD_T12	16	4.6	1.5	-1.41	1.48	0.019
U_CC_T12	14	1.7	1.3	U_CC_T12	17	4.2	1.6	2.45	1.43	<.0001

Table 7. Expansion stages for Group 2.

Group 2					
Variable	N	Mean	Std Dev	Minimum	Maximum
U_66_Exp	19	4.2	1.2	2.4	7.4
U_EE_Exp	18	4.1	1	2.4	6.8
U_DD_Exp	18	4.1	1	2.6	6.6
U_CC_Exp	19	3.9	1.4	1.2	6.9
U_66_PExCh	19	0	1.6	-2.3	3.4
U_EE_PExCh	16	0.9	2	-3.4	4.7
U_DD_PExCh	16	0.4	1.4	-2.5	2.8
U_CC_PExCh	17	0.3	1.6	-2.3	4.6

Table 8. Predictability of expansion.

Predictability										
		Group 1 %		Group 2		%				
Variable	N	Mean	Std Dev	Variable	N	Mean	Std Dev	Diff	SD	P
U_66_Eff	15	56.6	21.1	U_66_Eff	19	82.3	20.2	-25.68	20.57	0.001
U_EE_Eff	9	68.9	12.8	U_EE_Eff	16	88.4	26.8	-19.47	22.96	0.05
U_DD_Eff	3	63.3	13.8	U_DD_Eff	14	82	19.1	-18.76	18.51	0.13
U_CC_Eff	7	42	33	U_CC_Eff	15	80.1	20.5	-38.06	24.87	0.0032

Table 9. Predictability of expansion with the first set of clear aligners.

	Group 1			Group 2			
Variable	**N**	**Mean**	**Std Dev**	**Variable**	**N**	**Mean**	**Std Dev**
U_66_Eff12	15	48.8	23.6	U_66_Eff12	19	79.8	19.7
U_EE_Eff12	14	62.3	21.6	U_EE_Eff12	16	89.3	26.9
U_DD_Eff12	12	58.8	21.9	U_DD_Eff12	16	85	18.3
U_CC_Eff12	14	53.6	31.1	U_CC_Eff12	16	78.9	19.8

Table 10. Expansion predictability – changes in inclination.

Group 1						Group 2					
UR6_Inc_T12	15	5.9	8.1	-9.2	21.7	UR6_Inc_T12	19	6.2	6.8	-2.8	16.7
UL6_Inc_T12	16	8	6.8	-2.6	21.9	UL6_Inc_T12	19	6.7	7.3	-4.6	18.7
URE_Inc_T12	14	7.3	6	-0.5	19.6	URE_Inc_T12	18	5.6	6.6	-8.1	19.3
ULE_Inc_T12	0.	.	.	.		ULE_Inc_T12	0.	.	.	.	
URD_Inc_T12	13	7.2	4.9	-0.6	17.8	URD_Inc_T12	16	4.3	5.2	-6.8	15
ULD_Inc_T12	12	5.5	10.2	-14.9	20.6	ULD_Inc_T12	16	8.9	6.4	-5.1	17.6
URC_Inc_T12	14	7.6	6.2	0.7	20.3	URC_Inc_T12	17	9.1	7	-3.2	22.9
ULC_Inc_T12	16	7.4	6.7	-1.1	21.6	ULC_Inc_T12	18	7.3	6	-2	19.9
UR6_Inc_T12	15	6	10.2	-10.9	21.7	UR6_Inc_T13	19	0.7	14.8	-36.8	16.4

Table 11. Expansion efficiency – inclination.

Group 2					
UR6_Inc_Exp	19	6	7.6	-5.6	24.8
UL6_Inc_Exp	19	5.7	5	-3.2	12.8
URE_Inc_Exp	19	4.8	3.8	-1.1	13.1
URD_Inc_Exp	18	5.5	4.4	-6.8	16.8
URC_Inc_Exp	18	9.5	5.9	-2.3	21.2
ULC_Inc_Exp	18	7.3	6.4	-1	17.3
ULD_Inc_Exp	18	9.4	3	3.5	13.7
ULE_Inc_Exp	0 .	.	.	.	
UR6_Inc_PExCh	19	0.2	9.3	-14.8	15.4
UL6_Inc_PExCh	19	1	7.2	-12.6	13.9
URE_Inc_PExCh	18	1.1	5.8	-9.8	10.9
URD_Inc_PExCh	16	-1.1	4.2	-11.5	8.3
URC_Inc_PExCh	17	-0.8	8.9	-16.5	14.8
ULC_Inc_PExCh	17	0	5.5	-9.9	8.8
ULD_Inc_PExCh	16	-0.4	5.1	-11.2	9.1
ULE_Inc_PExCh	0 .	.	.	.	

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