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Predictability of Maxillary Dentoalveolar Expansion Using Clear Aligners in Different Types of Crossbites

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Abstract: The aim of this study was to determine the efficacy and predictability of maxillary dentoalveolar expansion clear aligners in unilateral, bilateral, and single-tooth types of crossbite. This prospective analytical study enrolled adults with dentoalveolar posterior crossbite. Orthoanalyzer™ 1.7 software was used to analyze stl files of digital models before treatment (T1), predicted post-treatment outcome (T2), and observed outcome (T3). Changes in intercanine width, first and second interpremolar widths, and intermolar width were compared using a mixed ANOVA model for repeated measures ($\alpha = 0.05$). The study included 46 patients aged 20–60 years, 15 with unilateral, 15 bilateral, and 16 single-tooth crossbite. In all crossbite groups, expansion was largest at the second premolar level (unilateral: 2.54 mm; bilateral:, 4.86 mm; single-tooth: 3.41 mm) (ANOVA $p < 0.001$) and smallest at the canine level. Expansion predictability was 90% at the first premolar level in the single-tooth crossbite group, 86% at the second premolar level in the bilateral crossbite group, and 79% at the second premolar level in the unilateral crossbite group. No significant difference was found between the predicted and observed expansion in any crossbite group. Dentoalveolar expansion using differential anchorage techniques with clear aligners is highly predictable, although the treatment plan should consider overcorrection of the expansion movement to achieve the planned outcome.

Keywords: dentoalveolar expansion; clear aligners; transverse malocclusion; crossbite; orthodontic treatment

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Citation: Nogal-Coloma, A.; Yeste-Ojeda, F.; Rivero-Lesmes, J.C.; Martin, C. Predictability of Maxillary Dentoalveolar Expansion Using Clear Aligners in Different Types of Crossbites. *Appl. Sci.* **2023**, *13*, 2963. https://doi.org/10.3390/app13052963

Academic Editors: Andrea Scribante and Paola Gandini

Received: 7 February 2023
Revised: 20 February 2023
Accepted: 23 February 2023
Published: 25 February 2023

1. Introduction

The term transversal malocclusion refers to skeletal and/or dentoalveolar anomalies that may or may not include a posterior crossbite, defined as occlusion of a vestibular cusp in the fossa of a lower tooth [1–3]. A differential diagnosis is essential to determine the skeletal or dentoalveolar etiology of these malocclusions. Furthermore, we should also consider the possibility of a functional deviation generating a posterior crossbite [2].

Resolution of maxillomandibular discrepancies in the transverse plane requires compensatory coronal and/or radicular torque movements, basal expansion, or orthodontic treatment, combined with orthognathic surgery when the malocclusion is of skeletal origin in an adult patient. However, orthodontics is the sole approach to malocclusions of dentoalveolar origin, using fixed multibracket appliances or clear aligner systems [3–6].

Today, clear aligners are a real orthodontic alternative to traditional appliances that offer greater comfort, better aesthetics, better oral hygiene, and a more positive patient experience. Furthermore, clear aligners are capable of correcting dentoalveolar crossbite, resulting in an adequate interarch transverse coordination. However, clear aligners might not be as effective as braces in producing adequate occlusal contacts, controlling teeth torque, and increasing the transverse dimension [7].

Numerous authors have investigated the expansion attained with conventional orthodontic systems and clear aligners [6–13]. A prospective cohort study [6] concluded that low-friction self-ligating brackets produced significantly more transverse dentoalveolar width and perimeter of maxillary arch compared to clear aligners. Expansion is not only used to correct transversal problems, but also malocclusions with marked crowding as a means of gaining space [14–17]. However, reports on the application of clear aligners to correct transverse malocclusions have not specified the working mechanics or sequencing utilized for this purpose. Furthermore, most studies were conducted using EX30, an older material that has been replaced by SmartTrack (Align Technology, Santa Clara, CA, USA), making evaluations of the updated system necessary. Many earlier studies had methodological errors, small sample sizes, inadequate statistical analyses, low or moderate risks of bias, or high levels of heterogeneity.

Kesling [18] first introduced the idea of differential anchorage, proposing two distinct phases: dental crown inclination and root straightening. Researchers have developed sequences of movements or "staging" [17–20] in relation to the correction of sagittal [21] and vertical malocclusions [14]; however, differential anchorage has not been defined or established as a treatment option to correct transverse malocclusions.

Clear aligners offer an advantage over conventional orthodontic systems, in which an undesired movement results from a desired one, in accordance with Newton's law of an equal and opposite action for every action. The clear aligner system allows these undesired movements to be controlled and minimized, selecting teeth that should not be moved but rather act as support units within the same dental arch, enhancing anchorage [22]. Intra-arch differential anchorage with clear aligners, in which some teeth are supported to move others in the same arch, is useful for mesialization or distalization movements, as well as expansion, extrusion, and intrusion movements [14,21,22].

Similar to conventional orthodontic systems, inter-arch anchorage is accomplished through the use of elastics between the maxillary arch and the mandibular arch. This way, reaction forces in the opposing arch can be controlled. For correction of posterior crossbites, elastics are used from the palatal surfaces of the upper teeth to the buccal surfaces of the lower teeth to achieve this inter-arch anchorage. In addition to limiting the reaction forces in the opposing arch, this therapeutic approach allows controlling the buccal movement of the upper teeth. The compliance of the patient with the use of elastics is critical.

Literature has shown that the reliability of orthodontic tooth movement with clear aligners does not seem encouraging, and this treatment option does not completely fulfil the pretreatment goals at the end of the initially planned clear aligners treatment [23].

The objective of this study was to determine the predictability of dentoalveolar expansion with clear aligners (Invisalign®) in patients with different types of dentoalveolar crossbites.

2. Materials and Methods

This prospective analytical study was designed to establish the predictability of expansion movement with clear aligners. It was approved by the Ethics Committee of the Hospital Clínico San Carlos de Madrid (internal code 20/085-E_Tesis; date of approval: 30 April 2020), and all patients signed an informed consent form to participate. The manuscript was written in accordance with the recommendations for reporting clinical case series studies [24].

2.1. Sample Selection

Patients attending the private orthodontic clinic of one of the authors were enrolled in the study if they fulfilled specific eligibility criteria. Inclusion criteria were: age over 20 years, presence of dentoalveolar compression of the upper arch with unilateral, bilateral, or single-tooth crossbite; absence of missing teeth (excluding wisdom teeth) in the upper arch; complete permanent dentition, with the exception of third molars; no scheduled dental extraction; need for orthodontic expansion and orthodontic treatment on both arches; and willingness to be treated using clear aligners. Clinical and radiographic records were evaluated to determine the need for orthodontic expansion. Exclusion criteria were: being in the growth phase; reported previous orthodontic treatment; presence of craniofacial syndrome, systemic disease, periodontal disease, or active joint disorder before or during treatment; and need for treatment requiring therapeutic dental extraction or orthognathic surgery.

Patients who fulfilled the eligibility criteria were then scheduled for treatment using differential anchorage as the biomechanics of choice. Patient were divided into three groups according to their crossbite: bilateral crossbite, with at least two teeth (upper premolars and/or upper molars) in crossbite in both the right and left hemiarches (Group A); unilateral crossbite, with at least two teeth (upper premolars and/or upper molars) in crossbite in one hemiarch (Group B); or single-tooth crossbite of the upper first or second premolar or upper first molar (Group C). All patients were treated using the Invisalign® clear aligner system (Align Technology, San José, CA, USA), fabricated with Ex30™ and SmartTrack™ material. Treatment planning was completed using the ClinCheck® virtual model, which is a virtual treatment plan design tool developed by Align Technology, San José, CA, USA). Anchorage was determined by the type of posterior crossbite. In the unilateral group, anchorage was provided by the opposite dental arch. The bilateral group used the upper second molars and anterior teeth as anchorage. In the single-tooth group, adjacent teeth served as anchorage. To minimize anchorage loss, sequential movements were planned.

Patients were instructed to use the aligners 22 h/day for 10 days. Aligners change was scheduled every 10 days. Control appointments were fixed at 6-week intervals. Compliance was also verbally confirmed at each appointment.

Stereolithography (stl) files of digital models of all patients were obtained to perform the measurements using Orthoanalyzer™ 1.7 analytical software (3Shape, Copenhagen, Denmark). Three digital models were developed for each patient to show: the initial malocclusion, pretreatment (T1), the outcome predicted by the planning software (T2), and the post-treatment outcome before initial (T3).

Pretreatment stl files were obtained from the initial intraoral scans of the patients (T1). Final-stage stl files were exported from the ClinCheck software and labeled as "predicted outcome" (T2). Post-treatment files were also obtained from the intraoral scans taken after the first set of aligners and labeled as "achieved outcome" (T3) since they represented the actual outcome.

All stl files were deidentified. The following measurements were recorded in mm at each time point: intercanine width, first and second interpremolar width (mm), and intermolar width (mm). The effectiveness of expansion at the canine, premolar, and molar level was evaluated as the difference in widths between T3 and T1, calculating the percentage of the initial width achieved by treatment (T3 − T1%). The predictability of expansion at the canine, premolar, and molar level was assessed as the difference in measurements between T2 and T3, calculating the percentage of the final width not achieved by the treatment (T2 − T3%) and the percentage of relative predictability, i.e., the observed expansion relative to the predicted expansion ($T3 - T1 \times 100/\ T2 - T1$).

2.2. Statistical Analysis

Sampling was conducted by non-probabilistic recruitment of consecutive cases. The sample size was estimated to detect effects >1.86 mm (bilateral test), based on the study of patients with crossbite by Duncan et al. [11], with a significance level of $p \leq 0.05$ and a minimum power of 20%. The effect size of 1.43 was calculated by dividing the desired detectable mean difference by its standard deviation (SD), obtaining a sample size of 12 patients per group. The sample was increased to 15 patients per group to cover possible losses to the follow-up. After checking the normality of variable distribution with the Shapiro–Wilk test, demographic variables were compared using one-way ANOVA and Chi-Square tests.

Results from the crossbite groups were compared by using a mixed ANOVA for repeated measures and conducting a posteriori Bonferroni correction. The replicability of the measurements was evaluated with the intraclass correlation coefficient (ICC). The repeated measures of 10 patients were compared, with an interval of five days between each measurement. SPSS v27 (IBM SPSS, Armonk, NY, USA) was used for statistical analyses.

3. Results

Repeated measures of stl files from 10 patients measured twice showed an ICC index for intra-examiner agreement that ranged from 0.919 to 0.887, indicating the high reproducibility of the measurements.

3.1. Patient Characteristics (Table 1)

The study included 46 patients (27 women and 19 men) aged 20–60 years. Most participants included in this prospective observational study had skeletal class I (50%), mild skeletal class II (34.8%), or mild skeletal class III (15.2%) malocclusions, with no significant differences among groups ($p = 0.106$).

The unilateral crossbite group required a mean of 28 aligners (including all sets of aligners), and a mean treatment time of 15.5 months for the first set of aligners; 73% of these patients used intermaxillary crossbite elastics. The bilateral crossbite group required a mean of 32 aligners and mean treatment time of 15.2 months for the first set of aligners; 66.67% used intermaxillary crossbite elastics. The single-tooth crossbite group required a mean of 31 aligners and mean treatment time of 14 months for the first set of aligners; 46.67% used intermaxillary crossbite elastics. No statistically significant differences were found among the groups for gender ($p = 0.737$), age ($p = 0.778$), treatment duration ($p = 0.735$), or the percentage of patients who used crossbite intermaxillary elastics ($p = 0.657$).

Table 1. Characteristics of the sample. SD: standard deviation, %: percentage.

Group (Type of Crossbite)	Number of Patients (Male/Female)	Total Mean Number of Aligners (SD), Including Refinements	Mean Treatment Time for the First Set of Aligners in Months (SD)	% of Patients that Used Intermaxillary Elastics
Unilateral	15 (7/8)	28 (7.05)	15.5 (4.88)	73%
Bilateral	15 (6/9)	32 (15.57)	15.2 (7.54)	66.67%
Single-Tooth	16 (7/9)	31 (10.23)	14 (3.58)	46.67%

3.2. Expansion Efficacy

Table 2 exhibits within-group comparisons of the width changes between T1 (baseline) and T3 (expansion achieved) in each crossbite group. The percentage of the initial width increased by treatment was calculated, too, and expressed as T3-T1(%). The changes were statistically significant ($p \leq 0.05$) for all measurements in all three groups, except for the intercanine width in the unilateral crossbite group.

The largest expansion was achieved at the second premolar level in all three groups, being 4.86 mm in the bilateral crossbite group, with T3-T1(%) of 11.70%; 3.41 mm in the single-tooth crossbite group, with T3-T1(%) of 8.01%; and 2.54 mm in the unilateral crossbite group, with T3-T1(%) of 5.75%.

Expansion was greater at the first molar versus first premolar level in both the unilateral (2.08 mm vs. 1.65 mm) and bilateral (3.95 mm vs. 3.38 mm) crossbite groups, whereas it was greater at the first premolar versus first molar level (3.02 mm vs. 2.67 mm) in the single-tooth crossbite group.

Table 3 displays between-group comparisons of the width changes (T1-T3). The groups did not significantly differ in intercanine width changes ($p = 0.142$); however, significant between-group differences were observed in the amount of expansion at the first premolar level ($p = 0.03$), second premolar level ($p = 0.026$), and molar level ($p = 0.034$). At the first premolar level, the mean expansion was significantly larger in the bilateral versus unilateral crossbite group (mean difference of 1.73 mm; 95%CI 0.06–3.39 mm), whereas there was no significant difference between the single-tooth and unilateral or bilateral crossbite groups.

At the second premolar and first molar levels, the expansion was also significantly larger in the bilateral versus unilateral crossbite group at the second molar (mean difference of 2.31 mm; 95%CI 0.25–4.37 mm) and first molar (mean difference of 1.87 mm; 95%CI 0.11–3.63 mm) levels.

Table 2. Within-group comparisons of the efficacy (T3-T1) of expansion at canine, premolar, and molar levels. T1: pretreatment width; T3: post-treatment width; T3-T1(%): percentage of initial width increased by treatment. SD: standard deviation, %: percentage, CI: confidence interval, PRE: pre-treatment measure, POST: post-treatment measure, T3: actual end-expansion achieved, T1: beginning, mm: millimeters.

Within-Group Comparisons T3-T1			Mean ± SD	T3-T1 (mm)	95%CI	*p*-Value	T3-T1 (%)
Unilateral Crossbite	Canine	T1: PRE	33.58 ± 2.95	−0.14	−1.37 to 1.65	1	−0.42%
		T3: POST	33.44 ± 1.74				
	1st Premolar	T1: PRE	39.65 ± 2.49	1.65	−2.76 to −0.55	0.004	4.16%
		T3: POST	41.30 ± 2.44				
	2nd Premolar	T1: PRE	44.32 ± 2.60	2.54	−3.99 to −1.10	0.001	5.75%
		T3: POST	46.87 ± 1.99				
	1st Molar	T1: PRE	48.85 ± 2.65	2.08	−3.35 to −0.81	0.002	4.26%
		T3: POST	50.93 ± 2.08				
Bilateral Crossbite	Canine	T1: PRE	32.37 ± 2.56	0.91	−3.08 to −0.29	0.016	2.81%
		T3: POST	33.28 ± 1.89				
	1st Premolar	T1: PRE	37.82 ± 3.10	3.38	−4.91 to −1.86	<0.001	8.96%
		T3: POST	41.21 ± 2.69				
	2nd Premolar	T1: PRE	41.53 ± 3.95	4.86	−6.84 to −2.87	<0.001	11.70%
		T3: POST	46.39 ± 3.17				
	1st Molar	T1: PRE	46.35 ± 3.16	3.95	−5.33 to −2.58	<0.001	8.52%
		T3: POST	50.30 ± 3.20				
Single-Tooth Crossbite	Canine	T1: PRE	32.19 ± 1.81	1.01	−1.82 to −0.20	0.013	3.14%
		T3: POST	33.20 ± 2.10				
	1st Premolar	T1: PRE	37.64 ± 3.13	3.02	−4.17 to −1.88	<0.001	8.05%
		T3: POST	40.67 ± 2.53				
	2nd Premolar	T1: PRE	42.59 ± 3.56	3.41	−4.63 to −2.19	<0.001	8.01%
		T3: POST	46 ± 2.91				
	1st Molar	T1: PRE	47.10 ± 3.69	2.67	−4.03 to −1.30	<0.001	5.67%
		T3: POST	49.77 ± 3.53				

3.3. Expansion Predictability

Table 4 shows the differences between T2 (predicted outcome) and T3 (observed outcome) in the unilateral, bilateral, and single-tooth crossbite groups. Although the predicted expansion appeared greater than the observed expansion for all measurements in all groups, the difference was only significant for the intercanine width in the bilateral crossbite group ($p = 0.011$).

The highest % expansion predictability was for second interpremolar width in the unilateral and bilateral crossbite groups (79.19% and 86.02%, respectively) and for first interpremolar width in the single-tooth crossbite group (90.15%).

Table 3. Between-group comparisons of the efficacy (T3-T1) and predictability (T2-T3) of expansion at canine, premolar, and molar levels. T1: initial width; T2: predicted final width; T3: observed final width. 3-3: intercanine, 4-4: inter-first premolar, 5-5: inter-second premolar, 6-6: intermolar, UNILAT: unilateral crossbite group, BILAT: bilateral crossbite group, single tooth: single-tooth crossbite group, Vs.: versus, CI: Confidence interval, Lim: limit, *: statistically significant difference, $p \leq 0.05$.

Between-Group Comparisons		BILAT Vs. UNILAT			Single Tooth Vs. UNILAT			Single Tooth Vs. BILAT		
		Mean Difference	95% CI		Mean Difference	95% CI		Mean Difference	95% CI	
			Lower Lim	Upper Lim		Lower Lim	Upper Lim		Lower Lim	Upper Lim
3-3 width changes (mm)	T3 − T1	1.06	−0.53	2.65	1.15	−0.41	2.72	0.097	−1.47	1.66
	T2 − T3	−0.48	−1.2	0.25	−0.04	−0.75	0.68	0.44	−0.28	1.15
	ANOVA *p*-value	0.142								
4-4 width changes (mm)	T3 − T1	1.73 *	0.06	3.39	1.37	−0.27	3.01	−0.36	−2	1.28
	T2 − T3	0.05	−1.09	0.98	−0.35	−0.67	1.37	−0.4	−0.62	1.42
	ANOVA *p*-value	0.03 *								
5-5 width changes (mm)	T3 − T1	2.31 *	0.25	4.37	0.87	−1.16	2.9	−1.45	−3.48	0.58
	T2 − T3	0.13	−1.23	0.99	−0.28	−0.81	1.37	−0.41	−0.69	1.49
	ANOVA *p*-value	0.026 *								
6-6 width changes (mm)	T3 − T1	1.87 *	0.11	3.63	0.59	−1.15	2.32	−1.28	−3.02	0.45
	T2 − T3	0.02	−1.23	1.2	−0.33	−0.87	1.52	−0.35	−0.86	1.54
	ANOVA *p*-value	0.034 *								

The lowest % expansion was for intercanine width in both the unilateral group (−93.33%, i.e., compression, not expansion) and the bilateral group (54.17%, respectively) and at first molar level in the single-tooth crossbite group (65.76%).

Table 3 displays between-group comparisons of the predictability (T2-T3) of expansion (T2-T3) at the canine, premolar, and molar levels. No statistically significant differences were found for any comparison between the groups (95%CI contains the value 0).

Table 4. Within-group comparisons of the predictability (T2-T3) of expansion at canine, premolar, and molar levels. T2: predicted final width; T3: observed final width post-treatment. T2-T3(%): percentage of final width not achieved by treatment. Relative predictability (%) calculated as observed versus predicted amount of expansion (T3-T1 × 100/ T2-T1). SD: standard deviation, %: percentage, CI: confidence interval, PRED: predicted, POST: post-treatment measure, T2: predicted outcome, T3: observed outcome, T1: baseline, mm: millimeters.

Within-Group Comparisons T2 − T3			Mean (mm) ± SD	T2-T3 (mm)	95% CI	*p*-Value	T2-T3 (%)	% Relative Predictability: (T3-T1 × 100/T2-T1)
Unilateral Crossbite	Canine	T2: PRED	33.73 ± 1.88	0.29	−0.30 to 0.88	0.597	0.87%	−93.33%
		T3: POST	33.44 ± 1.74					
	1st Premolar	T2: PRED	41.98 ± 1.97	0.68	−0.36 to 1.72	0.296	1.65%	70.82%
		T3: POST	41.30 ± 2.44					
	2nd Premolar	T2: PRED	47.54 ± 1.99	0.67	−0.27 to 1.62	0.221	1.43%	79.19%
		T3: POST	46.87 ± 1.99					
	1st Molar	T2: PRED	51.65 ± 2.07	0.72	−0.22 to 1.66	0.167	1.41%	74.29%
		T3: POST	50.93 ± 2.08					

Table 4. *Cont.*

Within-Group Comparisons T2 − T3			Mean (mm) ± SD	T2-T3 (mm)	95% CI	*p*-Value	T2-T3 (%)	% Relative Predictability: (T3-T1 × 100/T2-T1)
Bilateral Crossbite	Canine	T2: PRED	34.05 ± 2.04	0.77	0.17 to 1.37	0.011	2.31%	54.17%
		T3: POST	33.28 ± 1.89					
	1st Premolar	T2: PRED	41.94 ± 2.60	0.73	−0.01 to 1.47	0.053	1.77%	82.28%
		T3: POST	41.21 ± 2.69					
	2nd Premolar	T2: PRED	47.18 ± 3.06	0.80	−0.20 to 1.80	0.145	1.70%	86.02%
		T3: POST	46.39 ± 3.17					
	1st Molar	T2: PRED	51.03 ± 3.44	0.74	−0.32 to 1.79	0.239	1.45%	84.40%
		T3: POST	50.30 ± 3.20					
Single-Tooth Crossbite	Canine	T2: PRED	33.53 ± 1.85	0.33	−0.15 to 0.80	0.243	0.99%	75.37%
		T3: POST	33.20 ± 2.10					
	1st Premolar	T2: PRED	40.99 ± 2.63	0.32	−0.21 to 0.87	0.365	−0.53%	90.15%
		T3: POST	40.67 ± 2.53					
	2nd Premolar	T2: PRED	46.39 ± 3.01	0.39	−0.15 to 0.94	0.213	0.85%	89.74%
		T3: POST	46 ± 2.91					
	1st Molar	T2: PRED	51.16 ± 3.48	0.39	−0.39 to 1.18	0.58	2.79%	65.76%
		T3: POST	49.77 ± 3.53					

4. Discussion

This study evaluates the efficacy of differential anchorage, sequenced biomechanics with clear aligners to achieve expansion movement in patients with unilateral, bilateral, or single-tooth crossbites. In general, the highest predictability was observed for expansion at the premolar level and the lowest for expansion at the canine level.

In this study, all patients were treated by the same experienced clinician. This fact reduces the variability associated with the virtual treatment design (attachments' design and placement, tooth movement staging, and aligners biomechanics knowledge), which plays a crucial role in defining the quality of the orthodontic treatment with aligners. It also improves the treatment achievement, since inconsistency due to the orthodontist's performance is controlled, too.

We have used both percentages and raw data to describe our results. Reporting percentage changes gives the results of a trial in clinical terms that are easily accessible to clinicians and patients. However, according to Vickers [25], the percentage change from baseline has been demonstrated to be statistically inefficient. Therefore, it is important to provide the real amount of analyzed movements, and use raw data, too.

The demographic characteristics of the patients and the outcomes related to their initial malocclusion and treatment features were similar for the three groups, which helps to control possible confounding variables that could influence the treatment results.

The mean expansion ranged from 1.01 to 4.86 mm, similar to the range of 2 to 4 mm reported by Morales et al. [1], who used a different software package (Keynote) for the measurements. The largest expansion was at the premolar level (4.86 mm) and the smallest at the canine level in the present series, as also found in Invisalign®-treated patients by Duncan et al. [12], who used Geomagic™ software and recorded a maximum expansion of 4.86 mm at the premolar level. In the same line, Pavoni et al. [6] described significantly greater dentoalveolar expansion at the second premolar level in the upper arch of patients treated with the Invisalign® technique, while changes at the molar level were not statistically significant.

Regarding the bucco-lingual linear translation of the teeth, Castroflorio et al. [8] revealed the worsening of the obtained outcome, moving from the center to the distal portion of the aligner, with losses increasing from 0.1 to 0.3 mm for every prescribed mm from incisors to premolars, and to 0.5 mm for every mm of prescribed movement for first molars. Similar results were found in the systematic review by Rossini et al. [23] on the efficacy of arch expansion with clear aligners.

The predictability of the treatment outcome was highest for measurements at the premolar level in all crossbite groups (79.19% for the second premolar in the unilateral crossbite group, 86.02% for the second premolar in the bilateral crossbite group, and 90.15% for the first premolar in the single-tooth crossbite group). The predictability was lowest for measurements at the canine level (−93% in the unilateral crossbite group and 54% in the bilateral group). Morales et al. [1] described similar predictability results of 80.3% at the first premolar level and 81% at the second premolar level, observing the lowest predictability at the second molar level, which they attributed to the correct position of this molar in 90.4% of their series. It would be of interest to include measurements of permanent second molars in future research. Houle et al. [11] described a mean predictability of 72.8% for changes in the width of the upper arch; however, in contrast to the present findings, they reported that the intercanine width was the most predictable measure, with the distance between the gingival margins of first molars being the least predictable. Kravitz et al. [26] observed that the predictability of expansion was only 40.5% at the incisor and canine level in both arches, mainly attributing the expansion movement to dental crown tilt; however, they did not study the predictability at the premolar and molar levels.

Charalampankis [27] investigated the accuracy of clear aligners in 20 adult patients, determining differences between the predicted and observed movements in both arches. Greater accuracy was achieved for upper interpremolar expansion than for upper intercanine expansion, which significantly differed between the predicted (2.09 mm) and observed (1.60 mm) outcomes. These results are in line with the present findings and explained by the longer roots of maxillary canines and the morphology of conical crowns, with fewer undercuts to enhance aligner retention.

Solano et al. [10] concluded that expansion planned with the ClinCheck® virtual model was not predictable for gingival or cuspid widths at the canine level, first or second premolar levels, or first molar level. In comparison to the present study, their study sample was larger (n = 116), but no information was provided on the planning of malocclusion correction; in addition, they treated patients with Ex30® material, whereas both Ex30 and SmartTrack® materials were used in the present study, hampering the comparability of findings.

To our best knowledge, this is the first study to compare the efficacy of clear aligners among patients with different types of crossbites, and more research is required on any differences and their clinical implications. Castroflorio et al. have shown that the prescribed movement, the moved teeth, the employment of attachments, and the frequency of aligner changes may influence the lack of correction [8]. Considering the planned movement, the more the planned movement increases, the more the lack of correction increases. Regarding the aligner change regime, he found significant differences for certain movements when comparing 7-days to 14-days aligner change. No significant differences were found between the 7-days and 10-days categories.

All these factors should be taken into account when planning the correction of different types of dentoalveolar posterior crossbites.

Further CBCT studies are warranted to determine how much of the expansion obtained in the present study is attributable to coronal tilt. Previous studies have shown that tipping and torque movements are the most difficult movements to control with aligners [13], and the loss of information increases movement toward the distal portion of the aligner [8].

5. Conclusions

- In all three crossbite groups, the largest expansion was achieved at the second premolar level. Second premolars showed the highest percentage of initial width increased by

treatment in all groups, too, except the single-tooth group, where similar percentages for the first and second premolars were found.
- In all three groups, the planned expansion was greater than the observed expansion. In the unilateral and bilateral crossbite groups, the highest predictability (79.19% and 86.02%, respectively) was for the second interpremolar width. In the single-tooth crossbite group, the highest predictability (90.15%) was for expansion at the first premolar level.

Author Contributions: Conceptualization, A.N.-C., F.Y.-O., J.C.R.-L. and C.M.; methodology, C.M.; software, A.N.-C.; validation, A.N.-C., F.Y.-O. and C.M.; formal analysis, C.M.; investigation, A.N.-C. and J.C.R.-L.; resources, F.Y.-O. and J.C.R.-L.; data curation, A.N.-C.; writing—original draft preparation, A.N.-C. and C.M.; writing—review and editing, A.N.-C., F.Y.-O. and C.M.; visualization, A.N.-C.; supervision, C.M. and F.Y.-O.; project administration, C.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Hospital Clínico San Carlos de Madrid (internal code 20/085-E_Tesis; date of approval: 30 April 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: BIOCRAN Research Group and Department of Dental Clinical Specialties UCM.

Conflicts of Interest: The authors declare no conflict of interest.

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