applied sciences

MDPI

Article

Assessment of Dental Arch Width Expansion Effectiveness Using a Novel Hybrid Aligner with Virtual Brackets and Nickel–Titanium Archwires: A Prospective Clinical Study

Jhonny Leon-Valencia [1], Jose Antonio Alarcon [2,3] and Conchita Martin [1,2,*]

[1] Department of Orthodontics, Faculty of Odontology, University Complutense of Madrid, 28040 Madrid, Spain; valenciaortodoncia@gmail.com (J.L.-V.); jalarcon@ugr.es (J.A.A.)
[2] BIOCRAN (Craniofacial Biology: Orthodontics and Dentofacial Orthopedics) Research Group, University Complutense of Madrid, 28040 Madrid, Spain
[3] Department of Stomatology, Faculty of Odontology, University of Granada, 18071 Granada, Spain
* Correspondence: mariacom@ucm.es

Abstract: *Objectives*: This study aimed to evaluate the effectiveness of a novel hybrid aligner system, Geniova Technologies™ (GT), for arch expansion and to compare the predictability of its virtual setup with a conventional clear aligner system (CA) after the first treatment phase. *Materials and Methods*: Forty (mean age: 31.3 years for GT, 38.4 years for CA) adult patients with maxillary dentoalveolar compression and anterior crowding >3 mm were enrolled and assigned to GT and CA groups. Transverse changes for canines and premolars were measured at the cusp and cervical levels. *Results*: No significant baseline differences in transverse dimensions were found between groups. Treatment duration (4.25 months for GT vs. 9.75 months for CA) and the number of aligners (4.25 in GT vs. 28.25 in CA) significantly differed ($p < 0.001$). At the cusp level, mean transverse expansions for the maxillary first premolars were 2.78 mm (GT) and 2.44 mm (CA). However, effectiveness comparisons revealed no significant differences in expansion outcomes, with both groups showing similar accuracy. *Conclusions*: The GT group achieved comparable dentoalveolar expansion of canines and premolars in significantly less time and with fewer aligners than the CA group. The predictability of virtual setup measurements was similar for both systems, confirming their comparable performance in achieving planned expansion.

Keywords: hybrid aligner; clear aligner; dentoalveolar expansion; predictability; expansion effectiveness

check for updates

Academic Editors: Eduardo Moreira Da Silva and Laiza Tatiana Poskus

Received: 22 November 2024
Revised: 20 December 2024
Accepted: 23 December 2024
Published: 24 December 2024

Citation: Leon-Valencia, J.; Alarcon, J.A.; Martin, C. Assessment of Dental Arch Width Expansion Effectiveness Using a Novel Hybrid Aligner with Virtual Brackets and Nickel–Titanium Archwires: A Prospective Clinical Study. *Appl. Sci.* **2025**, *15*, 39. https://doi.org/10.3390/app15010039

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

In recent years, the demand for orthodontic treatments with aesthetic appliances has increased exponentially, leading to the widespread adoption of clear aligner therapy (CAT). Clear aligners also offer several advantages over traditional fixed orthodontic appliances, including enhanced comfort, reduced frequency of emergencies, improved oral hygiene, and minimized soft tissue irritation [1–6].

Numerous studies have consistently confirmed that CAT has emerged as a viable alternative to conventional orthodontic therapy. It is particularly effective in treating mild to moderate malocclusions in non-growing patients who do not require extractions [7]. However, while CAT has demonstrated efficacy in various tooth movements, certain limitations persist. According to the scoping review by Muro et al. [8] and other studies [9], CAT has been shown to be particularly effective for buccolingual tipping but less predictable for rotational, intrusive, and extrusive movements. Moreover, while CAT has been shown to be effective for mild to moderate crowding resolution, the success of overbite correction still seems to be limited.

Dentoalveolar expansion is another movement where CAT has demonstrated effectiveness, although it is mainly achieved through posterior tooth tipping movement [10–16]. Arch expansion can be used to resolve mild to moderate crowding, to increase the width of the smile, or to correct certain crossbites of dentoalveolar origin [17–20]. The systematic review by Ma et al. [21] on the clinical outcome of arch expansion with CAT concluded that in the maxilla, the expansion rate decreases from the anterior to the posterior, with the highest efficacy observed in the premolar area. Although predictability is reasonable for expansion movements, published data indicate that arch expansion is not completely predictable. Despite variations in the methods used to quantify the predictability of expansion movement among the published papers, it ranges from 65.2% (for the maxillary second molar crown) [10] to 93.53% (for the maxillary first premolar) [14]. To address this limitation, overcorrection of movements is widely recommended at the virtual planning stage [10,13,15,21]. However, some patients may still require case refinement, mid-course correction, or conversion to fixed appliances before the end of treatment [22]. Additionally, some authors consider that CAT might not be as effective as braces in increasing the transverse dimension [23–25].

In this study, a novel treatment modality, Geniova Technologies™ (GT) (developed by Geniova Technologies, SL, Madrid, Spain), which combines CAT and braces, is tested with the aim of maintaining the advantages of both devices while reducing their limitations. Specifically, GT can be described as a hybrid aligner that includes virtual brackets and nickel–titanium archwires and combines principles of conventional orthodontics fixed appliances with the characteristics of CAT. GT comprises components and properties that differ from those of a conventional clear aligner, despite operating in a similar manner and involving patient interaction. For this study, the GT hybrid aligner system was designed to facilitate anterior dentoalveolar expansion, primarily targeting the premolar and canine regions. Unlike conventional clear aligners (CA), which rely on the continuous distribution of force across the dental arch through flexible polymer materials, the GT system introduces a segmented aligner design that integrates nickel–titanium (NiTi) archwires. These archwires generate consistent and sustained forces through their interaction with virtual brackets, which are digitally customized to optimize the biomechanical requirements of each movement. This approach not only creates the necessary space for mild to moderate crowding resolution but also improves buccal corridor aesthetics through controlled buccal tipping. By using molars as anchorage sectors, the system effectively achieves transverse expansion in canines and premolars, aligning its design principles with its intended use and highlighting its suitability for specific clinical cases. This hybrid system operates in distinct treatment phases, utilizing the hybrid aligner in the initial stages and transitioning to conventional aligners in the subsequent phases until treatment completion. This system is designed to accelerate certain dental movements during the early phases of CAT. Although GT and CA systems operate under distinct biomechanical principles, their reliance on precise virtual planning setups ensures comparable predictability in achieving planned dental movements.

This study addresses a significant gap in the current orthodontic literature by evaluating a novel hybrid aligner system, Geniova Technologies™ (GT), which combines elements of clear aligner therapy (CAT) and conventional fixed appliances. While CAT has been extensively studied and proven effective for mild to moderate malocclusions, it remains less predictable for complex tooth movements such as transverse expansion. Conventional fixed appliances, on the other hand, often provide better biomechanical control but lack the aesthetic and hygienic advantages of CAT. By integrating the strengths of both systems, the GT hybrid aligner offers a unique approach to orthodontic treatment. This study not only evaluates the efficacy and predictability of GT for transverse expansion but also provides a direct comparison with conventional CAT, offering clinicians evidence-based insights into the clinical applications and limitations of hybrid aligner systems. These findings have the potential to advance treatment planning strategies and expand the therapeutic possibilities for orthodontists. The null hypothesis for this study is that there are no differences in the effectiveness and predictability of transverse movements at the canine and premolar regions between treatments using conventional aligners and those using a hybrid aligner system.

The aims of the present study were twofold: firstly, to evaluate the efficacy of GT for arch expansion, and secondly, to assess the predictability of GT virtual setup measurements compared to conventional CAT at the end of the first treatment phase.

2. Materials and Methods

This prospective clinical study was approved by the Ethics Committee of the Hospital Clínico San Carlos de Madrid (internal code 19/294-R_P Tesis; date of approval: 23 July 2019), and all patients provided written informed consent to participate. The manuscript was prepared following the recommendations for reporting clinical case series studies [26].

2.1. Sample Selection

Patients attending the private orthodontic clinic of one of the authors were enrolled in the study if they met the following eligibility criteria. Inclusion criteria were as follows: Adult subjects ($\geq$21 years) with dentoalveolar compression of the maxillary arch (as assessed using the Schwartz method), presence of maxillary anterior crowding >3 mm, absence of missing teeth (excluding wisdom teeth), need for orthodontic expansion and orthodontic treatment of both arches lasting more than 6 months, no scheduled dental extraction, willingness to be treated using clear aligners, and cooperative patients. Exclusion criteria were as follows: Presence of craniofacial syndrome, systemic disease, periodontal disease, TJM disorders, subjects undergoing treatment with NSAIDs, bisphosphonates, or phenytoin, reported previous orthodontic treatment, and need for treatment requiring therapeutic dental extraction or orthognathic surgery.

After a thorough explanation of the study and according to the patient's preferences, selected patients were assigned to one of two groups based on the treatment modality to be applied: GT group and conventional clear aligner group.

2.1.1. GT Group

This group was treated with the GT system with the aim of creating expansion in the posterior sectors (canines and premolars). Every hybrid aligner was worn for 4 weeks. Treatment planning was completed using a 3D virtual visualization developed by the GT Company.

The hybrid aligners consist of the following components, Figures 1 and 2: Caps, which are aligner segments that may encompass one or more teeth, containing intrinsic information of virtual brackets and attachments tailored to the tooth anatomy; Virtual Brackets, digitally designed lingual brackets composed of a pyramidal base and a rectangular prism, with customized size and position; and Nickel–Titanium (NiTi) Archwires, standard 0.014″ nickel–titanium archwires with a round cross-section that provide smooth and continuous forces. This biomechanical component is directly linked to the virtual bracket and provides varying deflection and force to facilitate the planned tooth movements.

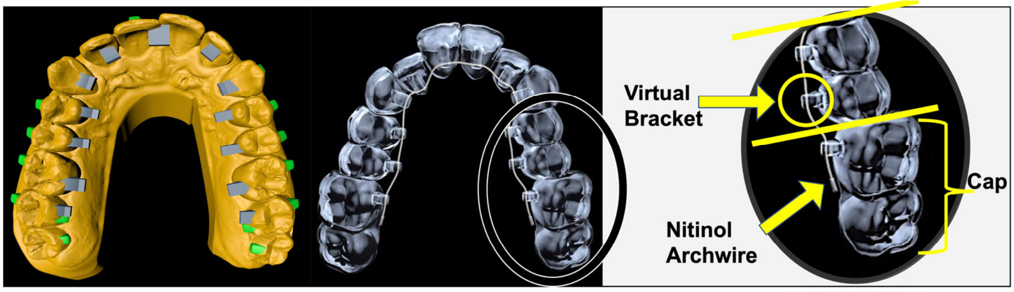

Figure 1. Illustration of the GT hybrid aligner system, showing the archwire inserted at the molar region, which serves as an anchorage point to stabilize the archwire and support expansion in the premolar and canine regions.

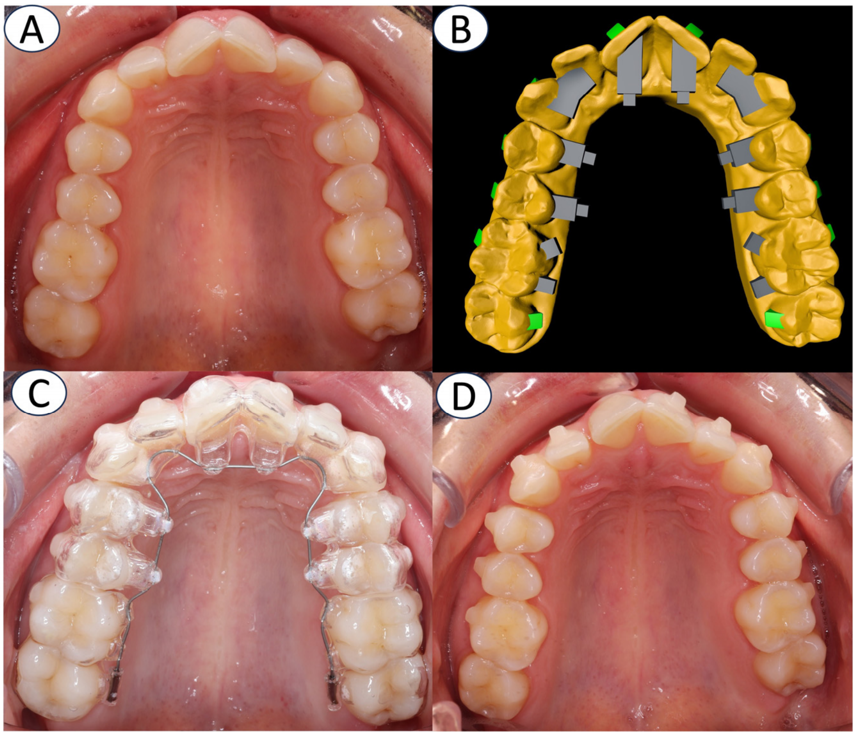

Figure 2. Hybrid aligner placed in a patient from the GT group. (**A**): picture previous to treatment. (**B**): digital treatment design. (**C**): first day of hybrid aligner in the mouth. (**D**): picture after 2 months of treatment.

2.1.2. Clear Aligner Group

This group was treated using the Invisalign® clear aligner system (Align Technology, San José, CA, USA), fabricated with SmartTrack™ material, with the aim of creating expansion in the posterior sectors. Every aligner was worn for 10 days. Treatment planning was completed using the ClinCheck® virtual model.

Patient compliance was monitored consistently in both groups. For the GT group, patients were instructed to wear the hybrid aligners for 22 h per day, removing them only for eating and oral hygiene. Compliance was assessed during follow-up visits every four weeks, where aligner fit and wear patterns were inspected, and patients were queried about their adherence to the prescribed wear time. For the CA group, patients followed similar instructions, with aligners changed every 10 days. Follow-up appointments every 6–8 weeks included assessments of aligner fit and wear patterns were inspected.

The total number of aligners used was recorded as an indicator of treatment efficiency. The GT system typically requires fewer aligners, each worn for longer periods (4 weeks per aligner), whereas the CA system uses a greater number of aligners with shorter wear durations (10 days per aligner). This difference reflects the distinct biomechanical approaches of the two systems and was considered in the comparison of their effectiveness and predictability.

2.2. Measurements

Intraoral scans were taken for every patient using a standardized protocol and the same device, the TRIOS scanner (3Shape, Copenhagen, Denmark), generating three digital models: Pre-treatment (T1), outcome predicted by the planning software (T2), and post-treatment (T3). The scanning protocol followed the manufacturer's guidelines to ensure consistent and accurate capture of the dental arch anatomy for all patients. Analysis of dental movements was conducted through dental superimpositions using the protocols developed by Choi et al. [27] and Cha et al. [28]. These protocols involved aligning the region of the palatal rugae on the hard palate, which serves as a stable reference for superimposition. Additionally, specific points on the teeth that were confirmed to remain stationary during treatment were selected as supplemental references to ensure accurate alignment and minimize error.

The following measurements were recorded in mm at each time point: upper and lower intercanine widths, inter-first premolar, and inter-second premolar widths, both at the vestibular cusps and at the middle lingual gingival level. All measurements were performed using OrthoAnalyzer 1.7 analytical software (3Shaphe, Copenhagen, Denmark). Only canines and premolars were included in the analysis because the GT system primarily targets these teeth for transverse expansion. Molars were excluded because the GT system uses them as an anchorage, and they do not receive active force application. This selection aligns with the study's objective of evaluating the clinical effectiveness and predictability of the systems in areas where both devices exert biomechanical forces.

The effectiveness of expansion was assessed by calculating the percentage of width achieved by treatment (T3-T1 %). The predictability of expansion was assessed by calculating the percentage of the observed expansion relative to the predicted expansion (T3-T1 $\times$ 100/T2-T1).

2.3. Statistical Analysis

Sampling was conducted using non-probabilistic recruitment of consecutive cases. The sample size was estimated to detect effects greater than 1.06 mm (bilateral test), based on the expansion study by Nogal-Coloma et al. [13], with a significance level of $p \leq 0.05$ and a minimum power of 80%, resulting in a sample size of 18 patients per group. The sample was increased to 20 patients per group to account for possible losses to follow-up.

To test the intra-rater reliability, 5 cases were randomly selected and measured twice. The measures were compared using the interclass correlation coefficient (ICC). For each variable analyzed, mean values and 95% confidence intervals were calculated after confirming that the outcomes met the assumption of normality. The analysis compared baseline measurements, treatment duration, number of aligners used, and dental expansion between the two treatment groups using an independent *T*-test. Statistical significance was set at $p \leq 0.05$.

3. Results

The ICC values were higher than 0.92 for all measurements, indicating that the measurements were reliable.

3.1. Patient Characteristics (Table 1)

The GT group was comprised of 20 patients, 5 male and 15 female, and the CA group consisted of 20 patients, 9 male and 11 female.

Average treatment duration (4.25 months for the GT group and 9.42 months for the CA group), number of aligners used (4.25 in the GT group vs. 28.25 aligners in the CA group), and age (31.3 years in the GT group vs. 38.45 years in the CA group) showed significant differences between groups ($p < 0.001$). No significant differences in transverse dimensions were found between groups at the beginning of the study (Table 1).

Table 1. Comparison of baseline (T0) measurements, treatment duration, and number of aligners used between GT (Geniova) and CA (clear aligner) groups. Tx: treatment; SD: Standard deviation; Diff: difference; CI: confidence interval; sig: significance; 13_23: upper canines; 14_24: upper first premolars; 15_25: upper second premolars; 33_43: lower canines; 34_44: lower first premolars; 35_55: lower second premolars; cusp: cuspid level; cerv: cervical level.

Outcome	GT		CA		Mean	95%CI		*p* (sig)
	Mean GT	SD GT	Mean CA	SD CA	Diff	Upper	Lower	
AGE (Years)	31.30	5.51	38.45	8.77	7.15	11.84	2.46	<0.001
Tx Duration (months)	4.25	0.72	9.42	2.17	5.16	6.56	4.44	<0.001
Number Aligners	4.25	0.72	28.25	10.20	24.00	28.78	19.22	<0.001
T0_13_23_cusp (mm)	33.10	2.98	31.77	2.01	−1.33	0.29	−2.96	0.105
T0_14_24_cusp (mm)	38.74	2.69	37.60	2.70	−1.14	0.61	−2.90	0.194
T0_15_25_cusp (mm)	43.73	3.01	42.97	3.11	−0.76	1.22	−2.75	0.440
T0_13_23_cerv (mm)	23.27	2.01	2.01	2.01	−0.87	0.39	−2.13	0.169
T0_14_24_cerv (mm)	25.42	1.95	24.69	2.09	−0.73	0.58	−2.04	0.266
T0_15_25_cerv (mm)	30.44	2.36	29.79	2.50	−0.66	0.92	−2.23	0.405
T0_33_43_cusp (mm)	23.55	6.76	25.21	1.49	1.76	4.81	−1.50	0.293
T0_34_44_cusp (mm)	32.25	3.07	30.97	2.47	−1.28	0.63	−3.18	0.182
T0_35_45_cusp (mm)	36.85	2.93	36.14	3.49	−0.71	1.56	−2.98	0.531
T0_33_43_cerv (mm)	18.98	2.26	18.34	1.58	−0.64	0.77	−2.05	0.358
T0_34_44_cerv (mm)	24.32	2.00	23.48	1.75	−0.84	0.45	−2.13	0.196
T0_35_45_cerv (mm)	27.93	2.09	27.48	2.78	−0.45	1.29	−2.20	0.601

3.2. Comparison of Dentoalveolar Width Changes Between the Two Groups

After treatment, an independent samples *t*-test was conducted to compare dental changes achieved between the two groups (Table 2). While the majority of variables showed no significant differences, significant changes were identified in specific areas of the lower arch: in the cusps between second premolars (mean difference: 1.50 mm, $p = 0.016$), favoring the CA group; and in the cervical regions between teeth first premolars (mean difference: 1.00 mm, $p = 0.008$), and second premolars (mean difference: 1.13 mm, $p = 0.010$), where the CA group exhibited greater expansion compared to the GT group too.

Table 2. Comparison of dentoalveolar width changes (Real) between GT (Geniova) and CA (clear aligner) groups. SD: Standard deviation; Diff: difference; CI: confidence interval; sig: significance; 13_23: upper canines; 14_24: upper first premolars; 15_25: upper second premolars; 33_43: lower canines; 34_44: lower first premolars; 35_55: lower second premolars; cusp: cuspid level; cerv: cervical level.

Outcome	GT		CA		Mean Diff	95%CI		*p* (sig)
	Mean GT	SD GT	Mean CA	SD CA		Upper	Lower	
Real_13_23_cusp	1.60	2.20	1.02	1.09	−0.58	0.54	−1.70	0.298
Real_14_24_cusp	2.78	2.03	2.44	1.40	−0.35	0.77	−1.46	0.533
Real_15_25_cusp	2.45	1.71	2.42	1.81	−0.03	1.09	−1.16	0.950
Real_13_23_cerv	0.88	1.25	0.96	0.82	0.08	0.75	−0.60	0.820
Real_14_24_cerv	1.66	1.28	1.67	0.91	0.01	0.73	−0.70	0.966
Real_15_25_cerv	1.37	1.13	1.50	1.34	0.13	0.92	−0.66	0.740
Real_33_43_cusp	0.81	1.41	0.18	1.33	−0.64	0.24	−1.52	0.150
Real_34_44_cusp	1.26	1.88	2.34	1.64	1.07	2.20	−0.06	0.062
Real_35_45_cusp	1.44	1.60	2.94	2.14	1.50	2.71	0.29	0.016
Real_33_43_cerv	0.28	0.79	0.62	0.99	0.34	0.91	−0.23	0.235
Real_34_44_cerv	0.83	1.09	1.83	1.17	1.00	1.72	0.27	0.008
Real_35_45_cerv	0.80	0.99	1.93	1.59	1.13	1.98	0.28	0.010

3.3. Comparison of Percentage Increase in Initial Width at Cusps and Cervical Points Between GT and CA Groups

Comparisons between groups were made based on the percentage increase of the initial width at cusps and cervical points. The analysis found no statistically significant differences between GT and CA treatments, indicating that both were equally effective in inducing relative increases in width (Table 3).

Table 3. Comparisons between groups based on the percentage increase of the initial width (T0%) achieved with the treatment. GT: Geniova; CA: clear aligner; SD: Standard deviation; Diff: difference; CI: confidence interval; sig: significance; 13_23: upper canines; 14_24: upper first premolars; 15_25: upper second premolars; 33_43: lower canines; 34_44: lower first premolars; 35_55: lower second premolars; cusp: cuspid level; cerv: cervical level.

Outcome	GT		CA		Mean Diff	95%CI		p (sig)
	Mean GT	SD GT	Mean CA	SD CA		Upper	Lower	
T0%_13_23_cusp	5.19	7.34	3.32	3.54	−1.88	1.86	−5.61	0.312
T0%_14_24_cusp	7.39	5.64	6.93	3.72	−0.46	2.66	−3.58	0.766
T0%_15_25_cusp	5.79	4.23	6.07	4.27	0.28	3.04	−2.48	0.839
T0%_13_23_cerv	4.05	5.80	4.45	3.84	0.40	3.55	−2.75	0.801
T0%_14_24_cerv	6.68	5.38	7.30	3.76	0.62	3.64	−2.41	0.682
T0%_15_25_cerv	4.63	3.92	5.44	4.49	0.81	3.54	−1.92	0.553
T0%_33_43_cusp	4.81	6.63	0.87	5.29	−3.93	0.16	−8.03	0.059
T0%_34_44_cusp	5.79	7.38	7.83	5.95	2.04	6.62	−2.54	0.372
T0%_35_45_cusp	5.44	4.81	8.56	6.65	3.12	7.25	−1.01	0.133
T0%_33_43_cerv	2.45	5.26	3.63	5.61	1.18	4.98	−2.61	0.530
T0%_34_44_cerv	4.94	5.47	7.93	5.31	2.99	6.73	−0.75	0.113
T0%_35_45_cerv	4.02	4.10	7.43	6.53	3.41	7.32	−0.50	0.085

3.4. Comparison of Predicted and Achieved Expansion Accuracy Between GT and CA Groups

The predictability assessment of virtual setup treatment outcomes, compared to actual results, was based on the percentage of achieved expansion relative to the planned expansion. Comparisons between the GT and CA groups showed no significant differences for all outcomes, indicating similar virtual setup predictability of expansion for both treatment modalities. In general, GT accuracy tended to be higher than CA for outcomes in the upper arch but lower for the lower arch, although the differences were not statistically significant (Table 4).

Table 4. Comparisons between groups based on the achieved percentage relative to the planned expansion (PredicAccur%). GT: Geniova; CA: clear aligner; SD: Standard deviation; Diff: difference; CI: confidence interval; sig: significance; 13_23: upper canines; 14_24: upper first premolars; 15_25: upper second premolars; 33_43: lower canines; 34_44: lower first premolars; 35_55: lower second premolars; cusp: cuspid level; cerv: cervical level.

Outcome	GT		CA		Mean Dif	95%CI		p (sig)
	Mean GT	SD GT	Mean CA	SD CA		Lower	Upper	
PredicAccur%_13_23_cusp	82.02	15.28	60.59	15.95	21.43	−23.28	66.14	0.338
PredicAccur%_14_24_cusp	84.13	14.57	58.04	5.72	26.10	−6.17	58.37	0.108
PredicAccur%_15_25_cusp	91.08	23.12	55.89	7.92	35.19	−15.32	85.71	0.163
PredicAccur%_13_23_cerv	95.99	32.36	43.43	5.63	52.55	−15.92	121.02	0.125
PredicAccur%_14_24_cerv	74.91	13.40	58.27	9.85	16.64	−17.34	50.63	0.327
PredicAccur%_15_25_cerv	77.49	21.06	49.29	6.91	28.20	−17.65	74.05	0.216
PredicAccur%_33_43_cusp	49.19	35.36	61.32	10.10	−12.14	−89.97	65.70	0.746
PredicAccur%_34_44_cusp	61.26	17.80	78.05	8.67	−16.78	−54.10	20.53	0.367
PredicAccur%_35_45_cusp	85.64	28.37	76.75	9.11	8.89	−54.37	72.15	0.735
PredicAccur%_33_43_cerv	42.41	26.49	46.87	12.85	−4.46	−60.50	51.59	0.872
PredicAccur%_34_44_cerv	77.41	11.95	83.64	9.07	−6.23	−36.25	23.80	0.676
PredicAccur%_35_45_cerv	56.58	24.14	78.33	23.73	−21.75	−91.90	48.40	0.533

4. Discussion

This work evaluated the efficacy and the predictability of the virtual setup of a novel treatment modality (GT) for dentoalveolar arch expansion, compared to conventional CA. The GT group had a lower average treatment duration and used fewer aligners compared to the CA group. Expansion was similar in both groups, except for the lower first and second premolars, which showed larger expansion in the CA group. The percentage of achieved expansion was similar for GT and CA groups at the cusps and cervical levels. Although the GT group showed non-significant greater prediction accuracy of expansion compared to the CA group in the upper arch, it was lower for the lower arch. In general terms, the predictability of virtual set-up measurements was similar for both the GT and CA groups.

The treatment modality in this study was not randomly assigned. However, the treatment planning for all patients was completed before the treatment modality was selected. This ensured that the initial malocclusion and treatment planning were not influenced by the specific system of aligners used, which was chosen based on the patient's preferences after the study was explained. Additionally, the treatment modality was not selected by the orthodontist after considering the patient's malocclusion, further supporting the independence of the treatment modality from the initial malocclusion.

It might be hypothesized that the results observed in the GT group (less treatment time and fewer aligners) could be due to the biomechanical properties of this novel system, which is based on principles of conventional multi-bracket appliances. Round nickel-titanium arches, ligated to the virtual brackets, generate continuous light forces for tooth movements. The difference in size and position between the virtual brackets generates movement in the three planes of space, as the brackets can change in size (height, width, and length) and position according to the desired design. Customization of the virtual bracket size in the GT appliance allows for greater or lesser deflection in the nickel–titanium arch during transverse movements, even in the absence of dental crowding. As an example, in cases of crossbites involving premolars without crowding, increased force can be generated due to the deflection caused by the virtual bracket size. This differentiates it from metallic brackets, which have a standard dimension and produce a 'constant' deflection force only when dental crowding is present. This could indicate that in cases of single-tooth crossbites, or a small group of teeth, the GT hybrid aligners may be more effective than conventional aligners and even traditional brackets due to the greater force generated by the deflection of the nickel–titanium arch. This biomechanics allows for faster achievement of transverse dental movement than aligners alone.

Fewer aligners may lead to a shorter treatment duration and fewer adjustments, which can be more convenient for patients. Moreover, it can result in lower treatment costs, making orthodontic treatment more accessible. Aligners are typically made of plastic, and using fewer aligners can reduce the amount of plastic waste generated during treatment and help reduce the carbon footprint associated with orthodontic treatment. This is particularly important from an environmental perspective, as plastic waste can have significant negative impacts on ecosystems and wildlife.

Transverse expansion has been achieved through various orthodontic techniques, each exhibiting distinct dentoalveolar and skeletal effects. Aligners, particularly the Invisalign® system, have gained prominence due to their aesthetic and patient-comfort advantages [29–32]. In terms of effectiveness, most authors agree that aligners produce primarily dentoalveolar changes, characterized by buccal crown tipping of posterior teeth [11,15,31–33], with the expansion being more effective in the premolar regions and less in the canines [10,15], and less predictable for the upper arch than for the lower arch [33]. In our study, the expansion achieved greater changes at cusps than at the cervical levels, indicating buccal crown tipping too. In the maxillary arch, the greatest expansion was observed at the first premolar area and the lowest at the canine area. Similarly, in the mandibular arch, the highest expansion rate was observed at the second premolar and the lowest at the canine in both groups.

Our data revealed mean transverse expansions at the cusp level of 2.78 mm for the GT group and 2.44 mm for the CA group in the maxillary first premolars, with both systems demonstrating similar efficacy in achieving dentoalveolar expansion at the cusp and cervical levels. These findings align with other clear aligner studies, which reported expansions ranging from 2.6 to 3.7 mm in mixed dentition and 2.2 to 3.2 mm in adults, primarily through controlled tipping [33]. However, these values are lower than those achieved with skeletal techniques such as SARPE and MARPE. For instance, SARPE achieved mean intermolar expansions of 7.0 mm, with skeletal contributions of approximately 3.3 mm [34], while MARPE demonstrated mean expansions of 5.67 mm in interpremolar and 6.18 mm in intermolar distances, offering more parallel expansion patterns and reduced dental tipping [35]. Nonsurgical, tooth-borne appliances like the Haas expander achieved expansions of 4.6 mm for molars and 5.5 mm for second premolars, accompanied by slight buccal tipping (3°) and alveolar displacement [36]. Lingual appliances achieved comparable dentoalveolar expansions, correcting up to 5 mm for posterior crossbites [37]. Unlike these methods, our findings focused exclusively on intra-arch expansion and did not address crossbite correction. Our study aligns with the consensus that aligners are effective for controlled dentoalveolar expansion, particularly in the premolar region. However, their efficacy for skeletal corrections or crossbite resolution remains limited. This highlights the importance of selecting expansion techniques based on patient-specific requirements and objectives.

The predictability of the aligner's expansion is usually assessed by comparing the virtual plan with the post-treatment digital models [30]. Predicted expansion varies between different studies; some authors found significant differences between the results planned on the virtual plan [10–12,16,29,31], while others did not find significant differences [15,38,39], even showing a high degree of predictability [32]. As the virtual plan, i.e., Clincheck®, tends to overestimate the expansion, many authors also plan an overcorrection during the expansion movement [2,31]. In our study, the virtual setup of GT and CA treatments showed similar predictability, although with a high degree of variability in both groups, ranging from 42.41% for lower canine cervical width to 95.99% for upper canine cervical width. The variability in the prediction of treatment outcomes was even higher in the GT group. The high degree of variability in the prediction of the results offered by the virtual setup is a common finding among the different authors [10–14,29–33], with percentages of predictability ranging from 45% [38] to around 98–100% [32].

The study findings offer valuable insights for orthodontic treatment planning. Clinicians should consider dental expansion efficacy, treatment duration, and predictability when selecting aligner systems. The GT system is effective for dentoalveolar expansion, offering clinical advantages like shorter first treatment phases and fewer aligners. Individualized treatment planning is crucial, considering patient-specific needs and aligner system characteristics for optimal outcomes and patient satisfaction. The GT system does not aim to induce active movements in the molars, despite the presence of the archwire in this region. Instead, the molars serve as anchorage points, stabilizing the archwire and facilitating targeted dentoalveolar expansion in the premolar and canine regions. This anchorage function is essential for the system's efficiency and precision in achieving controlled anterior expansion.

Among the limitations of the present study is the difference in the mean age of the groups, which was greater in the CA group. However, both groups consisted of adult patients in whom changes due to the growth of the dental arches were not expected to have influenced the results. Another factor to take into account when interpreting the results is that the GT system does not act on molars, while CA exerts force on the molars; this limitation of molars exclusion from the analysis ensures a fair comparison between systems, but it may limit the generalizability of the findings to cases where molar expansion is a clinical objective. Future studies could explore this aspect by including systems that apply forces uniformly across all teeth. As a consequence, there could be biomechanical factors that influence the observed differences.

The difference in wear protocols between the GT and CA systems is a limitation when directly comparing the total number of aligners. However, when considered alongside treatment duration, this metric provides valuable insights into the relative efficiency of the systems. The GT system achieves comparable results with fewer aligners and shorter treatment times, highlighting its potential advantages in clinical practice.

Future studies should consider expanding the comparisons to include conventional fixed appliances, such as labial and lingual braces. Such comparisons could provide additional evidence regarding the efficiency, predictability, and patient satisfaction of the GT system relative to traditional orthodontic techniques. This would further validate the advantages and limitations observed in the current study, offering a broader perspective on its clinical applications.

5. Conclusions

The GT group had a lower average treatment duration and used fewer aligners compared to the CA group.

Both groups demonstrated similar efficacy in achieving dentoalveolar expansion in the premolar and canine regions, with no significant differences at the cusp or cervical levels in either jaw.

The predictability of virtual set-up measurements was similar for both groups too.

These findings specifically address intra-arch expansion and do not provide evidence for crossbite correction. Further research is required to evaluate the efficacy of these systems for crossbite treatment or other applications.

Author Contributions: Conceptualization, J.L.-V., J.A.A. and C.M.; methodology, C.M.; software, J.L.-V.; validation, J.L.-V., J.A.A. and C.M.; formal analysis, C.M.; investigation, J.L.-V., J.A.A. and C.M.; resources, J.L.-V., J.A.A. and C.M.; data curation, J.L.-V.; writing—original draft preparation, J.L.-V., J.A.A. and C.M.; writing—review and editing, J.L.-V., J.A.A. and C.M.; visualization, J.L.-V.; supervision, C.M. and J.A.A.; 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.

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

References

1. Weir, T. Clear aligners in orthodontic treatment. *Aust. Dent. J.* **2017**, *62* (Suppl. S1), 58–62. [CrossRef] [PubMed]
2. Buschang, P.H.; Shaw, S.G.; Ross, M.; Crosby, D.; Campbell, P.M. Comparative time efficiency of aligner therapy and conventional edgewise braces. *Angle Orthod.* **2014**, *84*, 391–396. [CrossRef] [PubMed]
3. Mei, L.; Chieng, J.; Wong, C.; Benic, G.; Farella, M. Factors affecting dental biofilm in patients wearing fixed orthodontic appliances. *Prog. Orthod.* **2017**, *18*, 4. [CrossRef] [PubMed]
4. Nemec, M.; Bartholomaeus, H.M.; H. Bertl, M.; Behm, C.; Ali Shokoohi-Tabrizi, H.; Jonke, E.; Andrukhov, O.; Rausch-Fan, X. Behaviour of Human Oral Epithelial Cells Grown on Invisalign® SmartTrack® Material. *Materials* **2020**, *13*, 5311. [CrossRef]

5. Azaripour, A.; Weusmann, J.; Mahmoodi, B.; Peppas, D.; Gerhold-Ay, A.; Van Noorden, C.J.F.; Willershausen, B. Braces versus Invisalign®: Gingival parameters and patients' satisfaction during treatment: A cross-sectional study. *BMC Oral Health* **2015**, *15*, 69. [CrossRef]
6. Shalish, M.; Cooper-Kazaz, R.; Ivgi, I.; Canetti, L.; Tsur, B.; Bachar, E.; Chaushu, S. Adult patients' adjustability to orthodontic appliances. Part I: A comparison between Labial, Lingual, and Invisalign. *Eur. J. Orthod.* **2012**, *34*, 724–730. [CrossRef]
7. Papadimitriou, A.; Mousoulea, S.; Gkantidis, N.; Kloukos, D. Clinical effectiveness of Invisalign® orthodontic treatment: A systematic review. *Prog. Orthod.* **2018**, *19*, 37. [CrossRef]
8. Muro, M.P.; Caracciolo, A.C.A.; Patel, M.P.; Feres, M.F.N.; Roscoe, M.G. Effectiveness and predictability of treatment with clear orthodontic aligners: A scoping review. *Int. Orthod.* **2023**, *21*, 100755. [CrossRef]
9. Haouili, N.; Kravitz, N.D.; Vaid, N.R.; Ferguson, D.J.; Makki, L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. *Am. J. Orthod. Dentofac. Orthop.* **2020**, *158*, 420–425. [CrossRef]
10. Morales-Burruezo, I.; Gandia-Franco, J.L.; Cobo, J.; Vela-Hernandez, A.; Bellot-Arcis, C. Arch expansion with the Invisalign system: Efficacy and predictability. *PLoS ONE* **2020**, *15*, e0242979. [CrossRef]
11. Zhou, N.; Guo, J. Efficiency of upper arch expansion with the Invisalign system. *Angle Orthod.* **2020**, *90*, 23–30. [CrossRef] [PubMed]
12. Houle, J.P.; Piedade, L.; Todescan, R., Jr.; Pinheiro, F.H. The predictability of transverse changes with Invisalign. *Angle Orthod.* **2017**, *87*, 19–24. [CrossRef] [PubMed]
13. 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. [CrossRef]
14. Galluccio, G.; De Stefano, A.A.; Horodynski, M.; Impellizzeri, A.; Guarnieri, R.; Barbato, E.; Di Carlo, S.; De Angelis, F. Efficacy and Accuracy of Maxillary Arch Expansion with Clear Aligner Treatment. *Int. J. Environ. Res. Public Health* **2023**, *20*, 4634. [CrossRef]
15. Lione, R.; Paoloni, V.; Bartolommei, L.; Gazzani, F.; Meuli, S.; Pavoni, C.; Cozza, P. Maxillary arch development with Invisalign system. *Angle Orthod.* **2021**, *91*, 433–440. [CrossRef]
16. Solano-Mendoza, B.; Sonnemberg, B.; Solano-Reina, E.; Iglesias-Linares, A. How effective is the Invisalign® system in expansion movement with Ex30′ aligners? *Clin. Oral Investig.* **2017**, *21*, 1475–1484. [CrossRef]
17. Krishnan, V.; Daniel, S.T.; Lazar, D.; Asok, A. Characterization of posed smile by using visual analog scale, smile arc, buccal corridor measures, and modified smile index. *Am. J. Orthod. Dentofac. Orthop.* **2008**, *133*, 515–523. [CrossRef]
18. Womack, W.R.; Ahn, J.H.; Ammari, Z.; Castillo, A. A new approach to correction of crowding. *Am. J. Orthod. Dentofac. Orthop.* **2002**, *122*, 310–316. [CrossRef]
19. Giancotti, A.; Mampieri, G. Unilateral canine crossbite correction in adults using the Invisalign method: A case report. *Orthodontics (Chic.)* **2012**, *13*, 122–127.
20. Malik, O.H.; McMullin, A.; Waring, D.T. Invisible orthodontics part 1: Invisalign. *Dent. Update* **2013**, *40*, 203–204, 207–210, 213–215. [CrossRef]
21. Ma, S.; Wang, Y. Clinical outcomes of arch expansion with Invisalign: A systematic review. *BMC Oral Health* **2023**, *23*, 587. [CrossRef] [PubMed]
22. Rossini, G.; Parrini, S.; Castroflorio, T.; Deregibus, A.; Debernardi, C.L. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. *Angle Orthod.* **2015**, *85*, 881–889. [CrossRef] [PubMed]
23. Pavoni, C.; Lione, R.; Lagana, G.; Cozza, P. Self-ligating versus Invisalign: Analysis of dento-alveolar effects. *Ann. Stomatol. (Roma.)* **2011**, *2*, 23–27. [PubMed]
24. Ke, Y.; Zhu, Y.; Zhu, M. A comparison of treatment effectiveness between clear aligner and fixed appliance therapies. *BMC Oral Health* **2019**, *19*, 24. [CrossRef]
25. Kassam, S.K.; Stoops, F.R. Are clear aligners as effective as conventional fixed appliances? *Evid. Based Dent.* **2020**, *21*, 30–31. [CrossRef]
26. Jabs, D.A. Improving the reporting of clinical case series. *Am. J. Ophthalmol.* **2005**, *139*, 900–905. [CrossRef]
27. Choi, D.S.; Jeong, Y.M.; Jang, I.; Jost-Brinkmann, P.G.; Cha, B.K. Accuracy and reliability of palatal superimposition of three-dimensional digital models. *Angle Orthod.* **2010**, *80*, 497–503. [CrossRef]
28. Cha, B.K.; Lee, J.Y.; Jost-Brinkmann, P.G.; Yoshida, N. Analysis of tooth movement in extraction cases using three-dimensional reverse engineering technology. *Eur. J. Orthod.* **2007**, *29*, 325–331. [CrossRef]
29. Tien, R.; Patel, V.; Chen, T.; Lavrin, I.; Naoum, S.; Lee, R.J.; Goonewardene, M.S. The predictability of expansion with Invisalign: A retrospective cohort study. *Am. J. Orthod. Dentofac. Orthop.* **2023**, *163*, 47–53. [CrossRef]
30. Bouchant, M.; Saade, A.; El Helou, M. Is maxillary arch expansion with Invisalign® efficient and predictable? A systematic review. *Int. Orthod.* **2023**, *21*, 100750. [CrossRef]
31. D'Anto, V.; Valletta, R.; Di Mauro, L.; Riccitiello, F.; Kirlis, R.; Rongo, R. The Predictability of Transverse Changes in Patients Treated with Clear Aligners. *Materials* **2023**, *16*, 1910. [CrossRef] [PubMed]

32. Vidal-Bernardez, M.L.; Vilches-Arenas, A.; Sonnemberg, B.; Solano-Reina, E.; Solano-Mendoza, B. Efficacy and predictability of maxillary and mandibular expansion with the Invisalign® system. *J. Clin. Exp. Dent.* **2021**, *13*, e669–e677. [CrossRef] [PubMed]
33. Aragon, M.L.S.C.; Mendes Ribeiro, S.M.; Fernandes Fagundes, N.C.; Normando, D. Effectiveness of dental arch expansion in the orthodontic treatment with clear aligners: A scoping review. *Eur. J. Orthod.* **2024**, *46*, cjae059. [CrossRef]
34. Bortolotti, F.; Solidoro, L.; Bartolucci, M.L.; Incerti Parenti, S.; Paganelli, C.; Alessandri-Bonetti, G. Skeletal and dental effects of surgically assisted rapid palatal expansion: A systematic review of randomized controlled trials. *Eur. J. Orthod.* **2020**, *42*, 434–440. [CrossRef]
35. Chun, J.H.; de Castro, A.C.R.; Oh, S.; Kim, K.H.; Choi, S.H.; Nojima, L.I.; Nojima, M.D.C.G.; Lee, K.J. Skeletal and alveolar changes in conventional rapid palatal expansion (RPE) and miniscrew-assisted RPE (MARPE): A prospective randomized clinical trial using low-dose CBCT. *BMC Oral Health* **2022**, *22*, 114. [CrossRef]
36. Handelman, C.S.; Wang, L.; BeGole, E.A.; Haas, A.J. Nonsurgical rapid maxillary expansion in adults: Report on 47 cases using the Haas expander. *Angle Orthod.* **2000**, *70*, 129–144.
37. Schmid, J.Q.; Gerberding, E.; Hohoff, A.; Kleinheinz, J.; Stamm, T.; Middelberg, C. Non-Surgical Transversal Dentoalveolar Compensation with Completely Customized Lingual Appliances versus Surgically Assisted Rapid Palatal Expansion in Adults-The Amount of Posterior Crossbite Correction. *J. Pers. Med.* **2022**, *12*, 1893. [CrossRef]
38. Riede, U.; Wai, S.; Neururer, S.; Reistenhofer, B.; Riede, G.; Besser, K.; Crismani, A. Maxillary expansion or contraction and occlusal contact adjustment: Effectiveness of current aligner treatment. *Clin. Oral Investig.* **2021**, *25*, 4671–4679. [CrossRef]
39. Deregibus, A.; Tallone, L.; Rossini, G.; Parrini, S.; Piancino, M.; Castroflorio, T. Morphometric analysis of dental arch form changes in class II patients treated with clear aligners. *J. Orofac. Orthop.* **2020**, *81*, 229–238. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.