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Predictability of Maxillary Expansion with Invisalign® First: Treatment Planning vs. Outcome

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Abstract: The aim of this study is to retrospectively investigate the predictability of maxillary arch expansion with Invisalign ® First in mixed dentition. In a sample of 64 treated patients, 3D digital models from the ClinCheck® software were compared with post-treatment digital models. Predicted maxillary expansion was related to the final outcome of expansion. At the cuspidal level, there was observed a predictability of 59.68% for deciduous canines, 63.77% for first deciduous molars, 66.99% for second deciduous molars, and 55.61% for first permanent molars. At the gingival level, there was observed a predictability of 49.87% for deciduous canines, 53.11% for first deciduous molars, 53.36% for second deciduous molars, and 45.16% for first permanent molars. The difference between the predicted and achieved expansion was statistically significant ($p < 0.05$). Within the present limitations, our results suggest that, with Invisalign® First, it is possible to expand the upper arch in mixed dentition in an effective and predictable way. Clear aligners could represent a new and valid alternative for arch expansion in growing patients.

Keywords: palatal expansion technique; orthodontic appliances; removable; dentition; mixed; dentistry

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1. Introduction

Maxillary expansion treatments have been used for over a century to correct maxillary transverse deficiencies, and their efficacy is strongly supported in the literature [1]. In general, we can distinguish between two types of expansion: rapid maxillary expansion (RME) and slow maxillary expansion (SME). Both RME and SME are effective in increasing the maxillary transverse diameter in younger patients by opening the midpalatal suture, which is not fully ossified in growing individuals [2,3]. The purpose of RME is to create significant forces at the sutural site in a short period of time to maximize the orthopedic effect, while SME is achieved with lighter forces distributed over a longer period, leading to a more physiological expansion.

The Invisalign® technique was introduced in 1997 as an esthetic and comfortable alternative compared to conventional fixed appliances. Initially, treatment with clear aligners was intended for adult patients only. Compared to traditional appliances, it presents no dietary restrictions, lower risk of appliance damage due to its weekly change, no emergency appointments, simplified oral hygiene, greater patient comfort, easier compliance, and minimal social impact [4,5].

In 2018, Align Technology introduced the Invisalign® First system, consisting of clear aligners for patients aged from 6 to 10 years, to perform Phase I orthodontic treatment, including the correction of maxillary transverse deficit. Interceptive orthodontic interventions in early mixed dentition share the common goal of allowing for more favorable growth of the maxillae and the subsequent development of satisfactory occlusion. Common malocclusion traits in such treatments are arch constriction, molar rotations, and crowding, often associated with posterior crossbite, impacted teeth, and space loss for permanent dentition. In recent years, clear aligners have been proposed as a more convenient alternative to conventional approaches for achieving dentoalveolar maxillary expansion in growing patients (Figure 1) [6,7].

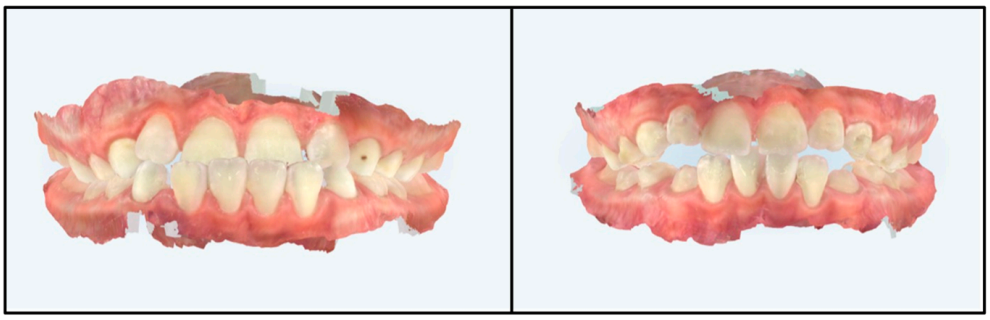


Figure 1. Anterior crossbite correction achieved with Invisalign® First clear aligners.

Currently, scientific knowledge on the predictability and effectiveness of Invisalign® as corrective treatments in mixed dentition is limited. Only few studies have evaluated the effectiveness of dentoalveolar expansion with Invisalign® First technology in mixed dentition [8,9]. Given the lack of data in the literature, especially concerning posterior transverse changes, this study aims to investigate the predictability of the ClinCheck® software (https://www.invisalign.com/provider/align-digital-platform/clincheck, accessed on 23 October 2024) by comparing the planned orthodontic setup measurements with the actual clinical outcome. Understanding the accuracy of the software in predicting changes could help the professional anticipate the need for overcorrection, thereby reducing refinements, mid-course corrections, and treatment time.

This study not only addresses a significant gap in the current literature, but also contributes to a better understanding of how aligner-based orthodontic treatments can provide a viable alternative to conventional methods. Comparing predicted outcomes with actual clinical results could offer an insights that can help practitioners improve their treatment planning strategies. The implications of this research are crucial for advancing orthodontic care in younger patients, particularly in improving predictability and reducing the need for refinements during treatment.

2. Materials and Methods

This study has been developed following the ethical standards established in the Declaration of Helsinki in 1975. Every participant provided informed consent and agreed to the privacy policy for the protection of personal data.

A sample of 64 subjects was required (statistical power set at 0.8). In this retrospective research, the sample consisted of 64 patients treated with Invisalign® First (Align Technology Inc., Tempe, AZ, USA) for maxillary expansion. The first aligner was worn for 14 days, and then aligners were changed weekly. The inclusion criteria were as follows: patients between 6 and 12 years old, mixed dentition, fully erupted maxillary first molar, at least 1 mm of maxillary expansion required, and complete diagnostic records. Patients with previous orthodontic treatment, requiring extraction, with craniofacial abnormalities, or with systemic syndromes were excluded.

For all of the patients, digital impressions were recorded with an iTero® intraoral scanner (Align Technology Inc., Tempe, AZ, USA) at the beginning and at the end of the treatment. Treatment was planned with the ClinCheck® software (Align Technology Inc., Tempe, AZ, USA), and the final desired outcome was digitally designed. To investigate whether the outcome designed with the ClinCheck® software was obtained during orthodontic treatment, the .stl files of the predicted outcomes were compared to the final scansion recorded on the patients at the end of the treatment. No further finishing phase was considered.

The following parameters were considered (Figure 2).

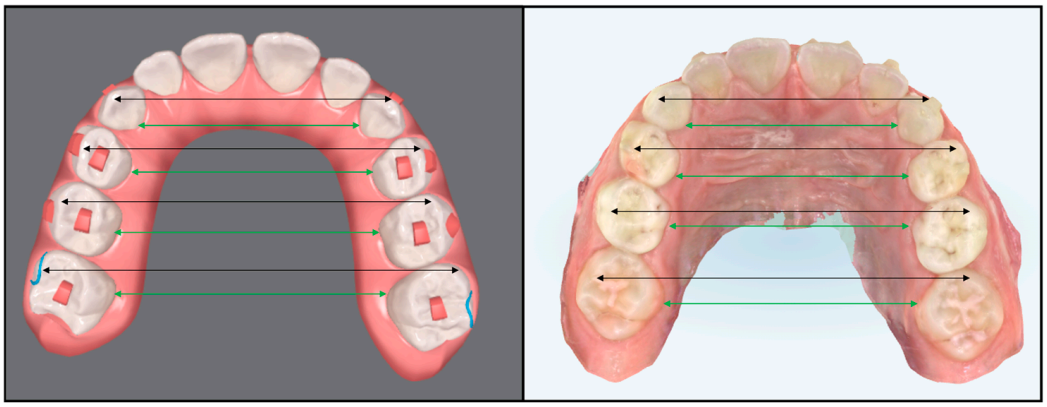


Figure 2. Linear measurements considered on the ClinCheck® software and on the digital scansions. Transversal diameters were measured at the cuspidal level (in black) and at the gingival level (in green).

Deciduous canine gingival diameter: Linear distance measured between the center of the palatal surface of the upper canines in contact with the gingival margin.

First deciduous molar gingival diameter: Linear distance measured between the center of the palatal surface of the first deciduous upper molars in contact with the gingival margin.

Second deciduous molar gingival diameter: Linear distance measured between the inner point of the palatal surface of the first deciduous upper molars in contact with the gingival margin.

First permanent molar gingival diameter: Linear distance measured between the inner point of the palatal surface of the first permanent upper molars in contact with the gingival margin.

Deciduous canine cuspidal diameter: Linear distance measured between the cusp tips of the upper deciduous canines.

First deciduous molar cuspidal diameter: Linear distance measured between the cusp tips of the deciduous upper first molars.

Second deciduous molar cuspidal diameter: Linear distance measured between the mesio-buccal cuspids of the second deciduous upper molars.

First permanent molar cuspidal diameter: Linear distance measured between the mesio-buccal cuspids of the first permanent upper molars.

These measurements were taken on the ClinCheck®, developed at the beginning of the treatment to create the treatment plan, and on the intraoral scansion of the patients recorded at the end of the treatment.

Statistical analyses was carried out. A Shapiro–Wilk test was used to verify whether the data were normally distributed. All measurements were calculated as average and standard deviations. A paired *t*-test was run to report any significant changes between measurements from the planned ClinCheck® and the achieved results at the end of the treatment. The statistical significance was set to $p < 0.05$. On 20% of the sample, measurements were taken twice by the same operator after 14 days. The intraclass correlation coefficient

(ICC) was used to assess reliability, showing a high degree of reliability (ICC > 0.98 for all measurements).

3. Results

In total, 64 patients were enrolled in the study (30 male and 34 female). The mean age was 8.7 years and ranged from 6.6 to 11.9, while the average treatment time was 9.8 months. The mean number of aligners was 33.2.

The results are summarized in Table 1.

Table 1. Results from the comparison between the planned and achieved expansion.

	Planned Expansion	Achieved Expansion	Δ	%	*p*-Value
Deciduous canine dental width	3.72	2.22	1.5	59.68%	$p < 0.05$
First deciduous molars dental width	4.37	2.78	1.5	63.77%	$p < 0.05$
Second deciduous molars dental width	4.5	3.01	1.48	66.99%	$p < 0.05$
First permanent molars dental width	4.52	2.51	2	55.61%	$p < 0.05$
Deciduous canine gingival width	3.59	1.79	1.8	49.87%	$p < 0.05$
First deciduous molars gingival width	4.22	2.24	1.98	53.11%	$p < 0.05$
Second deciduous molars gingival width	4.29	2.29	2	53.36%	$p < 0.05$
First permanent molars gingival width	4.12	1.86	2.26	45.16%	$p < 0.05$

The average planned expansion at the cuspid level was 3.72 mm for deciduous canines, 4.37 mm for first deciduous molars, 4.50 mm for second deciduous molars, and 4.52 for first permanent molars. The average planned expansion at the gingival level was 3.59 mm for deciduous canines, 4.22 mm for first deciduous molars, 4.29 mm for second deciduous molars, and 4.12 mm for first permanent molars. The average achieved expansion at the cuspid level was 2.22 mm for deciduous canines, 2.78 mm for first deciduous molars, 3.01 for second deciduous molars, and 2.51 for first permanent molars. The average achieved expansion at the gingival level was 1.80 mm for deciduous canines, 2.24 mm for first deciduous molars, 2.29 mm for second deciduous molars, and 1.86 mm for first permanent molars.

According to these data, the predictability of maxillary expansion at the cuspid level was 59.68% for deciduous canines, 63.77% for first deciduous molars, 66.99% for second deciduous molars, and 55.61% for first permanent molars, while the predictability of maxillary expansion at the gingival level was 49.87% for deciduous canines, 53.11% for first deciduous molars, 53.36% for second deciduous molars, and 45.16% for first permanent molars.

The statistical analyses show a significant difference between the planned setup and the achieved outcome.

4. Discussion

The purpose of this study was the evaluation of the predictability of maxillary expansion with Invisalign® First.

The Invisalign® First system, introduced by Align Technology in 2018, was designed to carry out Phase I orthodontic treatment using aligners. Phase I treatment is typically performed with arch expanders and represents interceptive treatment for growing patients. Using clear aligners, it is possible to perform simultaneous movements in all three spatial dimensions. This means it can address a range of common orthodontic issues such as dental crowding, diastema, deep overbite, open bite, and increased overjet. In addition, clear aligners offer other advantages over traditional fixed appliances, such as reducing negative effects on the periodontium, enabling better oral hygiene, and providing a more comfortable and esthetic treatment alternative [10].

Upper arch expansion with clear aligners is one of the most discussed topics in modern orthodontics. With Invisalign®, it is possible to expand the maxillary arch in the permanent dentition, but the increase is mainly due to tipping movements [11]. In the systematic review by Rossini et al. [12], it was observed that the use of aligners is recommended for simple malocclusions. Treatment with aligners is effective in aligning and leveling arches in non-growing subjects. Intrusion movement is comparable with fixed orthodontics, while the control of extrusion and rotation movements is not as predictable. The use of attachments, elastics, and IPR is essential to enhance the predictability of orthodontic movements. The results obtained by Castroflorio et al. [13] are consistent with what Rossini et al. stated regarding the effectiveness of maxillary arch expansion with aligners. It was observed that the mechanical behavior of the distal portion of the aligners is similar to that of traditional fixed appliances. Furthermore, the amount of overcorrection for mild and moderate cases and the aligner change interval were evaluated. For most movements, a 7-day change interval is sufficient, while for torque and rotation control, a 14-day interval is required. The systematic reviews by Songyang Ma and Wang and Bouchant et al. also stated that the effectiveness of clear aligners in achieving maxillary transverse expansion is a feasible option for addressing dental crowding [11,14]. The effectiveness of expansion is higher in the premolar area. Maxillary expansion decreases from the anterior to the posterior segments, and the presetting of sufficient buccal root torque of the posterior teeth can result in improved expansion efficiency. When planning maxillary arch expansion with Invisalign®, it is necessary to consider overcorrection because Clincheck® software tends to overestimate the expansion movement compared to the clinical outcome, making movement predictability lower.

There are few studies in the literature that have assessed the discrepancy between planned expansion in ClinCheck® and the actual results achieved with Invisalign® aligners in adults. According to Houle et al., the average accuracy for cuspid level expansion movements is 82.9%, while for gingival margin-level expansion it is 62.7% [15]. These results are in line with Galluccio et al., who stated that the overall accuracy of expansion treatment with Invisalign® is 70%, regardless of the type of tooth [16].

Zhou and Guo reported significant differences between the planned and achieved expansion and observed a predictability that ranged from 68% to 79% for crown movements, while the predictability of bodily movement for the first upper molar was 36% [17].

Limited studies in the literature have evaluated maxillary expansion with the Invisalign® First protocol. In the investigation conducted by Levrini et al., a consistent amount of body expansion for canines, deciduous molars, and first permanent molars was observed. Molar inclination was also assessed due to its correlation with potential periodontal issues and was found to be comparable to that achievable with other traditional expansion techniques. It was speculated that the Invisalign® First system could lead to a physiological adaptation similar to that achieved with slow maxillary expanders [18]. Vinicius Merino da Silva et al. compared the effectiveness and efficiency of clear aligners and 2 × 4 fixed appliances in correcting maxillary incisor position irregularities in mixed dentition. Clear aligners and 2 × 4 mechanics showed similar effectiveness and efficiency in correcting maxillary incisor positions in mixed dentition. The choice of appliance should be guided by the preferences of the orthodontist and the patient's family [19]. Another comparison of different techniques was made in the retrospective study by Cretella Lombardo et al., with the aim to analyze morphological changes in the upper arch in mixed dentition after two expansion protocols, the Invisalign® First system, and rapid maxillary expansion (RME). Through morphometric analysis, it was found that Invisalign® First induced changes in the shape of the upper arch during expansion, while RME did not [20]. Treatment with aligners resulted in an improvement in the shape of the maxillary arch, while RME maintained the initial triangular shape. Therefore, it was observed that RME widened the palate and tilted the upper first molars more vestibular, while clear aligners caused a greater increase in canine width. In addition, Invisalign® First appears to be more efficient than RME in terms of expansion at the anterior segment of the arch, with better control of molar tipping and

greater palatal width increase. The prospective cohort study by Lu et al. compared the dento-skeletal effects of using the Invisalign® First system with Hass-type appliances [21]. According to the authors, both Hass-type appliances and Invisalign® First could effectively expand the maxilla in mixed dentition. The Hass-type expander show significant better efficiency for dental arch expansion, while no significant difference was reported regarding arch depth. According to Wang et al., with Invisalign® First, it is possible to expand the arches effectively without affecting molar inclination, even though the increase in the palatal surface area is not significant. Pinho et al. observed that interceptive treatment with Invisalign® is predictable and clinically effective for arch expansion, even though more sets of aligners could be required to obtain the outcome planned with the Clincheck® 9. Another investigation from Gonçalves et al. reported that the overall predictability of maxillary expansion with Invisalign® First is 62.6%; however, maxillary expansion was measured only at the cuspidal level [22].

In the present investigation, the predictability of maxillary expansion with Invisalign® First ranged from 45% to 67%. A lower predictability was observed when expansion was measured at the gingival margin, as a probable consequence of a more prominent tipping movement in the crown. Predictability in mixed dentition appears to be lower than in permanent dentition, and this could be explained by the essential modification that verify the mixed dentition. No additional aligners were considered in this study, and this aspect could affect the predictability of the outcome, as treatment with clear aligners implies finishing in more phases. Teeth exfoliation and eruption could certainly lead to fitting problems, prolonging the treatment time. In addition, compliance level in younger patients must be evaluated, even though, in the experience of the authors, younger patients undergoing clear aligners treatment usually show a high level of compliance. While comparing these results to RME, it is indeed important to underline that the predictability of traditional expansion techniques is far from high. Typically, a relapse rate of about 30–50% is observed, which deeply affects the efficacy of these treatments [23].

The results observed in the current investigation underline the importance of the development of a correct treatment plan and patient selection. The scientific evidence supports the efficacy and predictability of clear aligners to expand the upper arch; however, clinicians must be aware of the biomechanical limitations to achieve a correct treatment design. Further studies will need to investigate the possible variables linked to staging, attachment design, and manufacturing processes that could influence the predictability of treatments. Therefore, overcorrection represents a key factor when planning upper arch expansion. As seen in other studies, the ClinCheck® software tends to overestimate the expansion movement compared to the clinical outcome, and frequently leads to crown tipping movements. In this scenario, the ClinCheck® software does not only represent a setup tool, but it should also be intended as a guide for biomechanics, taking into active consideration the attachment's design and overcorrection. These elements are essential in managing complex movements and ensuring that the aligners effectively translate the digital plan into clinical reality. Proper utilization of ClinCheck® can optimize outcomes by reducing deviations between the predicted and actual tooth movements, thus enhancing treatment predictability and efficiency and ensuring better control over the biomechanical principles at play.

5. Conclusions

The use of clear aligners in mixed dentition for maxillary expansion offers many advantages regarding comfort, oral hygiene, and esthetics. Invisalign® First allows us, indeed, to expand the arches in an efficient and predictable way, even though the predictability could suffer from numerous changes that happen during teeth exfoliation that could affect the fitting of the aligners. The predictability of maxillary expansion with clear aligners is higher when measured at the cuspidal level, ranging from 55% to 67%, and lower when measured at the gingival level, ranging from 45% to 53%. These factors must be taken into account when digitally planning the treatment, adding overcorrection when needed,

applying reproducible clinical protocols, and using additional aligner to achieve the desired orthodontic outcome. Within the present limitations, our results suggest that, with Invisalign® First, it is possible to expand the upper arch in mixed dentition in an effective and predictable way. Clear aligners could represents a new and valid alternative for arch expansion in growing patients. Further research and clinical trials could help refine these protocols and optimize treatment efficacy for a broader range of cases.

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

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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

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