Efficiency of Invisalign First® to promote expansion movement in mixed dentition: a retrospective study and systematic review

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Abstract

Aim The present study aimed: i) to retrospectively evaluate the expansion movement predicted by the Clincheck® software and the achieved expansion using Invisalign First® in children needing maxillary expansion to correct malocclusions; and ii) to critically compare these clinical results with the outcomes obtained for maxillary expansion using conventional removable and cemented expanders.

Material and Methods The 3D digital models of the dental arches of 24 children undergoing orthodontic treatment exclusively with Invisalign First® aligners between 2018 and 2021 were sequentially selected for this study. Three digital models were analysed: pre-treatment (P0), the Clincheck®-predicted tooth positions (P1), and post-treatment (P2) models. The maxillary dental arch width and expansion efficiency were measured and calculated. An in-depth review of the available literature on maxillary expansion was performed following PRISMA guidelines.

Results Invisalign First® was able to achieve a total effectiveness of maxillary expansion of 62.6%, compared to the predicted movement. Similarly, the total effectiveness of mandibular expansion was 61.6%.

Conclusions Our data shows that Invisalign First® system can increase the arch width with maxillary expansion effectiveness, providing similar results to those achieved with conventional removable appliances. However, neither Invisalign First® aligners nor conventional removable expanders are as much efficient as cemented-retained appliances.

KEYWORDS efficiency, Invisalign First® aligners, maxillary expansion, mixed dentition, palatal expansion technique.

Introduction

Maxillary expansion is often used in cases of true maxillary insufficiency, to correct transverse skeletal and dental discrepancies, or to increase the perimeter of the upper arch [McNamaraa, 2000]. This can be clinically evidenced by the existence of a unilateral or bilateral posterior crossbite, dental arch narrowing, dental crowding or protrusion [Kutin and Hawes, 1969; McNamaraa, 2000; Araujo and Buschang, 2004; Phan and Ling, 2007; Oshagh et al., 2012; Waring, 2017]. The prevalence of posterior crossbite in individuals between 7 and 9 years of age is estimated to be between 8% and 16% [Oshagh et al., 2012], and this trend is not gender-specific [Kutin and Hawes, 1969; Chisari et al., 2014]. Importantly, the transition phase from the mixed dentition to the permanent one usually coincides with an intense growth of the children, which is characterised by multiple orthodontic and orthopaedic changes [Martins et al., 2009]. Dentists and specialists have several treatment options, and usually traditional cemented or removable expansion appliances are used.

The Invisalign First® system, introduced in 2018, has revolutionised interceptive orthodontic treatment [Ali and Miethke, 2012]. This removable appliance made of 0.75-mm-thick polyurethane is programmed to produce a 0.15- to 0.25-mm tooth movement [Houle et al., 2017]. It consists of a series of aligners exchanged every 7 days, over a treatment duration of 18 months.

Since Invisalign First® aligners are removable, patient motivation is key to achieve the intended outcome. It is mandatory to patient to wear the aligners 22h per day [Houle et al., 2017]. Noncompliance is one of the main disadvantages of removable appliances and can cause treatment hardships, taking more than the predicted time to achieve the intended objectives, or even returning to the initial malocclusion [de Rossi, de Rossi and Abrão, 2011; Naseri et al., 2020; Zhou and Guo, 2020].

To date, there are few data about the maxillary expansion movement with Invisalign First® system, especially regarding a comprehensive comparison between software-predicted and achieved expansion movements. This study aims to compare the Clincheck® planned expansion movement with the clinical achieved movement using 3D digitals models of children needing a palatal orthodontic expansion to correct malocclusions. Then, following a strict integrative and systematic literature review, the Invisalign First® system was compared to conventional removable and fixed expanders in terms of efficiency.

Material and Methods

Retrospective study

This retrospective study compiles and examine the digital models of a convenience sample of 24 patients requiring maxillary expansion and treated between September 2018 and March 2021. All patients were treated by Professor Teresa Pinho, specialist in orthodontics and Invisalign Diamond Provider, in her private orthodontic practice in the North of Portugal. This clinical trial was conducted according to the Declaration of Helsinki and it was approved by the Ethics Committee of the Instituto Universitário de Ciências da Saúde (Porto, Portugal).

Sample characterisation

A mixed-gender study sample composed by 11 males (45.8%) and 13 females (54.2%) between 6 and 12 years old undergoing orthodontic treatment exclusively with Invisalign First® system presented different malocclusions (Fig. 1) at different transitional periods of dentition (Fig. 2) always using the same references points of measurements. Tooth expansion was considered only when there was no transition from temporary to permanent dentition at the initial and final treatment time with the first round of aligners (Table 1).

In the analysed study sample, the clinician diagnosed/detected 19 cases of tooth crowding (42.2%), 10 cases of posterior crossbite (22.2%), five cases of anterior crossbite (11.1%), four cases of open bite (8.9%), three cases of deep bite (6.7%), and finally two cases presented overjet or Class II division 2 (II/2) malocclusion (4.4%).

At the beginning of the orthodontic treatment, 21 patients were in the first transitional period that usually occurs from 6 to 8 years old, which corresponds to the transition of incisors and emergence of the first permanent molars. Three patients were in the inter-transitional period, usually from 8 to 10 years old. This comprises a stable phase where the teeth present are the permanent incisors and the first permanent molar along with the temporary canines and temporary molars. Sixteen patients passed from the first transitional period to the inter-transitional period from the onset to the end of the orthodontic treatment. Five patients ended their treatment still in the first transitional period and three of them ended the treatment at the second transitional period, with the eruption of the permanent canines.

Eligibility criteria of the retrospective study

The following inclusion criteria was considered for participation in the current study: (i) children of at least 6 years old and no older than 10 years old with palatal malocclusion requiring orthodontic treatment; and (ii) first permanent molars fully erupted, with good tooth contour and sufficient height of clinical crowns. On the other hand, patients presenting periodontal, dental, or systemic disease that can affect tooth movement, orofacial malformations, or syndromes, or requiring an auxiliary treatment during the arch expansion stage were excluded from the study. As we already explained, tooth expansion was considered only when there was no transition from temporary to permanent dentition at the initial and final treatment time with the first round of aligners.

Clinical intervention

The entire orthodontic treatment lasted for 18 months with aligners exchanged every 7 days. All records were obtained with the iTero intraoral scanner and analysed with the Clincheck® software. Each patient was advised to use each aligner at least 22h per day [Houle et al., 2017]. Patient compliance is mandatory to achieve good results with aligners.

The present study analyses and discusses the data from the beginning to the end of the first round of aligners, and thus no refinement was included.

Clinical and virtual measurements

The 3D digital models for three different situations were inserted in the Invisalign® platform for comparison and analysis (see the tooth movement tables in Supplementary Materials 1): (i) pre-treatment tooth position (P0); (ii) planned positions after treatment, as predicted using Clinchek® software(P1); and (iii) achieved tooth positions after treatment with the first round of aligners (P2). The linear measurements of interdental widths at positions P0, P1 and P2 are listed in Table 1.

The landmarks (i.e., reference points used to perform the measurements: mesiopalatal cusp tip of the temporary and permanent molars, palatal cusp tip of the premolars, and cusp tip of temporary and permanent canine) were identical for all casts and are indicated in Figure 3.

Data analysis and statistical assessment

Tooth expansion was considered only when no transition from temporary to permanent teeth occurred during the treatment span. For statistical purposes, the expansion efficiency was calculated as a percentage of the achieved movement compared to the predicted using Equation 1 [Kravitz et al., 2009], which ensures that the percentage of efficiency (E) never exceed 100% for teeth that achieved movement beyond their predicted value.

$$E = 100\% - \left[\frac{|predicted(P1 - P0) - achieved(P2 - P0)|}{|predicted(P1 - P0)|} \times 100\% \right]$$

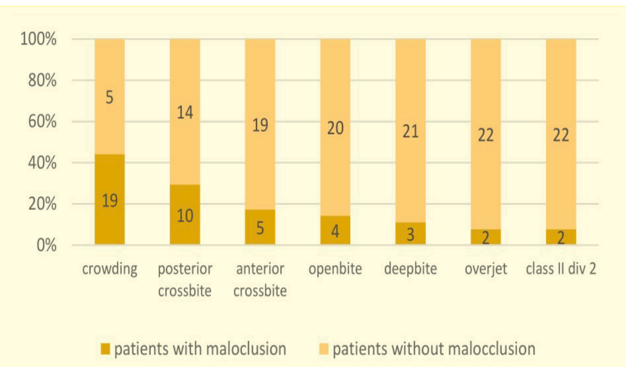

FIG. 1 Distribution of the malocclusions in the study sample.

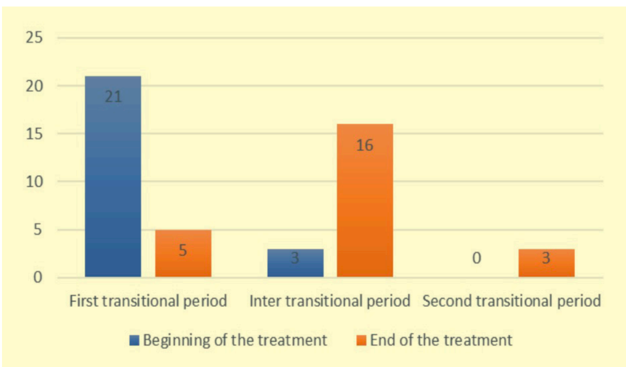

FIG. 2 Distribution of the patients in the different transitional periods of dentition.

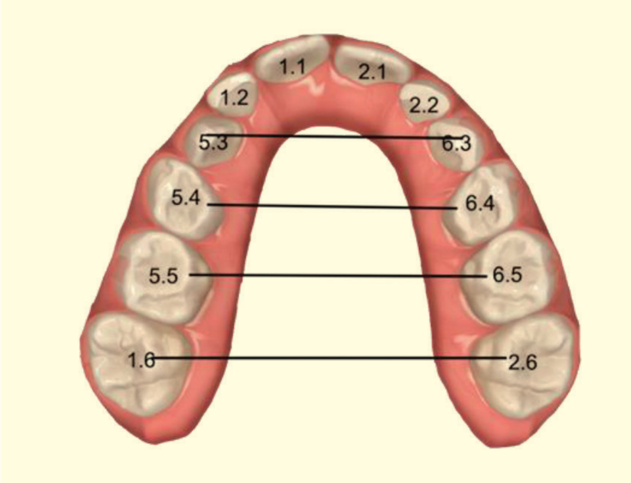

FIG. 3 Landmarks of transverse measurement in the maxillary arch.

Width from teeth cusp tips	
Upper temporary intercanine; Upper inter first premolar (palatal cusp tip); Upper inter second premolar (palatal cusp tip); Upper inter first temporary molar (mesiopalatal cusp tip); Upper inter second temporary molar (mesiopalatal cusp tip); Upper inter first permanent molar (mesiopalatal cusp tip);	Lower temporary intercanine; Lower permanent intercanine; Lower inter first premolar (lingual cusp tip); Lower inter second premolar (lingual cusp tip); Lower inter first temporary molar (mesiolingual cusp tip); Lower inter second temporary molar (mesiolingual cusp tip); Lower inter first permanent molar (mesiolingual cusp tip);

TABLE 1. Linear measurements of interdental widths at positions P0, P1 and P2.

Population	Clinical studies of human children or adolescents with mixed dentition who need interventional maxilla expansion treatment.
Intervention	Maxilla expansion treatment with removable of fixed appliances
Comparison	Control group of children not treated or baseline conditions.
Outcome	Linear measurements of interdental widths (e.g., intercanine, intermolar, maxillary widths of temporary and permanent dentition).
Study design	Prospective and retrospective clinical studies, community-based trial, randomized clinical trial.

TABLE 2 PICOS (Population, Intervention, Comparison, Outcomes and Study design) strategy applied in the current review.

Statistical analysis was performed using the IBM SPSS® Statistics 27 (Armonk, New York, USA). A descriptive analysis of all variables is presented. After normality evaluation using the Kolmogorov-Smirnov test, differences between the values obtained for maxillary and mandibular arches (i.e., predicted and achieved movements, the difference between these variables and mean efficacy), as well as the difference between predicted and achieved movements within each arch were evaluated using the Student's t-test for independent samples. A p-value of 0.05 was considered for statistical significance.

Systematic literature review

The review protocol used followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [Moher et al., 2009].

The articles included in this systematic review were selected according to the below criteria (Table 2), following the Population, Intervention, Comparison, Outcomes and Study design (PICOS) strategy.

Therefore, the focus question of the current systematic review was defined as: "How effective are Invisalign First® orthodontic aligners compared with traditional expanders in promoting tooth expansion movement?"

The following inclusion criteria were considered.

-Preclinical and clinical studies that perform linear measurements of distances between teeth or calculate expansion efficiency metrics.

- Articles whose study refers to patients with mixed dentition.

-Studies written in English.

- Papers published between 2010 and 2021.

Additionally, the following studies were excluded from the review:

-All article types except original research papers;

-Studies in patients presenting periodontal, dental or systemic disease that can affect tooth movement, orofacial malformations or syndromes, or requiring an auxiliary treatment during the arch expansion stage;

-Studies that do not clearly describe the type of orthodontic appliances used and the movement promoted by the orthodontic treatment;

- Application of an auxiliary treatment during the arch expansion stage.

Advanced searches were performed in PubMed, Cochrane Library, ESBCOhost, ScienceDirect, SciElo, Virtual Health Library and Scopus databases using the keywords: "orthodontic appliance", "palatal expansion technique", "transverse discrepancy", "mixed dentition", "outcome". This search was limited to papers written in English and published within 2010 to 2021. This period was chosen to thoroughly revise and focus on the last-decade data on the efficiency of different orthodontic appliances to promote expansion movement.

Finally, the methodological quality assessment of the eligible studies was performed according to the criteria detailed in the Cochrane Collaboration Handbook [Cumpston et al., 2019]. The Risk of bias in randomised trials (RoB 2.0) approach and the Risk Of Bias Assessment Tool for Non-Randomised Studies (ROBINS-I) were used to evaluate the randomised and observational studies, respectively.

Results

Retrospective study

A total of 24 patients were selected based on the inclusion criteria previously elicited, and a total of 73 maxillary teeth and 65 mandibular teeth were investigated (Table 3). A descriptive analysis of the variable under study is presented in Table 4. Some tooth type presented insufficient teeth to be considered a representative sample to perform the analysis (i.e., groups with two or less teeth), such as the upper first premolar (UPM1), upper second premolar (UPM2), lower permanent canine (LpermC), lower permanent canine (LpermC), and lower first premolar (LPM1). On the contrary, other groups of teeth allowed a clear

MAXILLARY TEETH									
Tooth type	N	Predicted (P)	SD	Achieved (A)	SD	Diff (P) - (A)	SD	Efficiency (E)	SD
UtempC	14	5.5	1.9	3.4	1.7	2.1	1.7	55.2%	21.2%
UtempM1	13	6.4	1.2	4.0	1.1	2.4	1.4	60.7%	13.4%
UPM1	2	7.7	0.6	4.9	1.5	2.9	0.9	63.0%	14.7%
UtempM2	19	6.4	0.7	4.0	1.2	2.3	1.0	63.3%	15.4%
UPM2	1	5.4	-	3.9	-	1.5	-	72.2%	-
UpermM1	24	4.6	0.6	2.8	1.5	1.8	1.4	61.1%	26.8%
TOTAL	73	6.0	1.0	3.8	1.4	2.2	1.3	62.6%	18.3%
MANDIBULAR TEETH									
Tooth type	N	Predicted (P)	SD	Achieved (A)	SD	Diff (P) - (A)	SD	Efficiency (E)	SD
LpermC	2	4.0	1.3	2.2	0.0	1.8	1.3	55.7%	20.1%
LtempC	9	2.2	1.6	1.2	1.4	1.1	0.8	52.2%	47.2%
LtempM1	12	4.0	1.8	1.9	1.8	2.2	1.4	46.2%	37.0%
LPM1	2	7.2	0.8	5.7	2.1	1.5	2.9	79.7%	25.7%
LtempM2	16	4.1	1.6	2.5	1.1	1.7	1.3	59.9%	28.6%
LpermM1	24	3.0	1.8	2.0	1.8	1.0	1.7	66.8%	49.1%
TOTAL	65	3.5	1.5	2.1	1.4	1.4	1.7	61.6%	32.1%

Abbreviations: UtempC: upper temporary canine; UtempM1: upper temporary first molar; UPM1: upper temporary first premolar; UtempM2: upper temporary second molar; UPM2: upper second premolar; UpermM1: upper permanent first molar; LpermC: lower permanent canine; LtempC: lower temporary canine; LtempM1: lower temporary first molar; LPM1: lower first premolar; LtempM2: lower temporary second molar; LpermM1: lower permanent first molar.

TABLE 3 Expansion movement efficiency and comparison between predicted and achieved expansion.

and conclusive analysis of the efficiency of the performed movement, namely the upper temporary canine (UtempC), upper temporary first molar (UtempM1), upper temporary second molar (UtempM2), upper first molar (UpermM1), lower temporary canine (LtempC), lower temporary first molar (LtempM1), lower temporary second molar (LtempM2), and lower first molar (LpermM1). A mean of planned transverse changes (i.e., predicted movement) was estimated by the Clincheck® software, and the mean difference between the amount of movement planned and achieved [i.e., column Diff (P) – (A)] was calculated.

Overall, the mean efficiency of Invisalign First® system for the overall tooth movement of the maxillary arch (62.6 ± 18.3% efficiency) was slightly greater than the total tooth expansion of the mandibular arch (61.6 ± 32.1% efficiency), however no statistically significant differences were found (Table 5). Although having a greater difference between the planned movement and the outcome (i.e., greater gap between predicted and achieved), the maxillary arch present higher expansion efficiency (E) due to the greater magnitude of the predicted movement compared to the mandibular teeth. This can also be confirmed from the mathematical relationship defined in Equation 1. Again, no statically significant differences were observed between the efficiency percentage in the dental arches (see Table 5). Also, Figure 4 depicts a graphical representation of the efficiency obtain for each tooth in the maxillary (Fig. 4a) and in the mandibular (Fig. 4b) arches.

The most accurate expansion tooth movements were the lower first premolar (79.7%), followed by the upper second premolar (72.2%), which was probably caused by the fact that those teeth are located on a straight line in the arches and usually have a single root, facilitating their movements. On the contrary, the least accurate expansion tooth movements were the lower temporary first molar (46.2%), followed by the lower temporary canine (52.2%) and the upper temporary canine (55.2%). Moreover, the lower teeth data had a greater dispersion (standard deviation of 32.1%) compared to the upper teeth (18.3%), showing that the heterogeneity in the amount of movement induced by the Invisalign First® was higher in the mandibular arch. Similar conclusions can be drawn based on the data provided in the descriptive analysis table (Table 4). This data suggests that Invisalign First® is more efficient in promoting the expansion movement in the upper teeth compared to the lower ones.

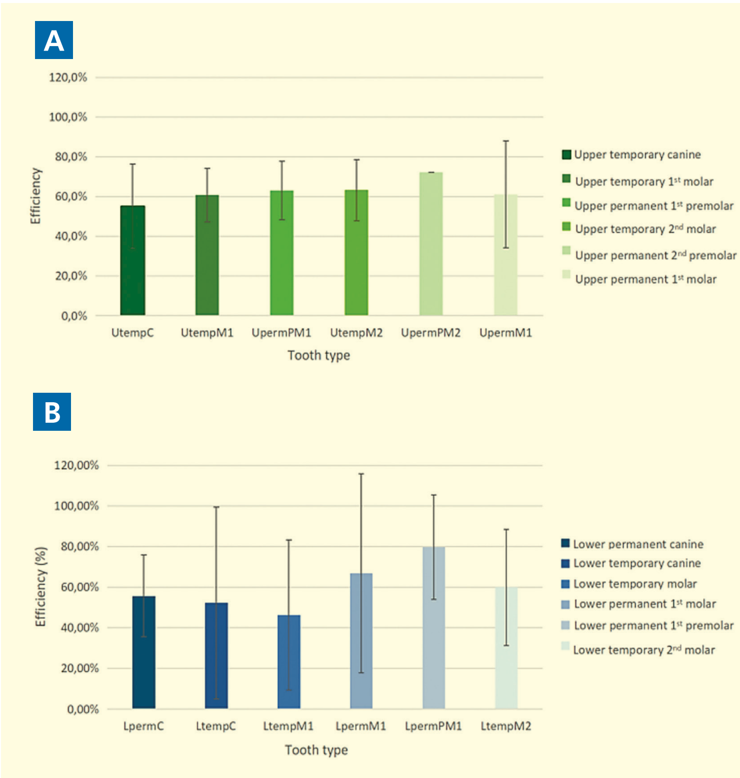

FIG. 4 Efficiency of a) maxillary; and b) mandibular expansion per teeth with the error bars based on the standard deviation.

Publication data	Study design	Objective	Population & orthodontic intervention	Measurement	Outcomes
Ramoglu S.I.& Sari Z. 2010 17 "Maxilla expansion in the mixed dentition: rapid or semi-rapid?"	Randomized clinical trial	To evaluate the effects of RME and SRME expansion.	SME: 18 patients (8.63 ± 1.09 yo) RME: 17 patients (8.78 ± 1.61 yo)	IC width between the cusp tips. IM width between the sulci.	No significant differences in dentofacial structures for transverse, sagittal and vertical plans between rapid and semi-rapid maxillary expansion. Maxilla: IC: 34.36± 4.07 mm; IM: 48.47± 4.07 mm. Mandible: IC: 27.91± 2.91 mm; IM: 43.43± 4.48 mm.
Huynh T. et al. 2010 25 "Treatment response and stability of slow maxilla expansion using Haas, hyrax, and quad-helix appliances: A retrospective study"	Retrospective study trial	To assess the stability of SME using Haas, Hyrax and QDH appliances.	Haas-type cemented expander: patients Hyrax cemented expander: 41 patients QDH cemented : 45 patients (overall average age: 8 yo)	IM maxillary width.	No significant differences in the expansion movement between Haas, Hyrax or QDH. SME showed stability rate of 84% for the posterior crossbite Maxilla: Haas IM:46.6 ± 2.7 mm QDH IM: 47.7 ± 2.8mm Hyrax IM: 47.5 ± 2.8mm
Weyrich C., Noss M. & Lisson J.A. 2010 18 "Comparison of a Modified RME Appliance with Other Appliances for Transverse Maxilla Expansion"	Randomized clinical trial	To compare a modified RME appliance with other appliances for transverse maxilla expansion.	Modified RME : 20 patients (8.77 ± 0.57 yo) RME : 10 patients (9.36 ± 1.26 yo) EP removable expander: 10 patients (9.46 ± 1.49 yo)	IM rate of maxillary expansion.	No significant differences in the amount of expansion movement between RME and modified RME. Significant differences in the amount of expansion movement between RME and EP, and modified RME and EP. More time required to activate and expand the maxilla for the modified RME than RME. Maxilla: Modified RME: IM: 5.74 ± 1.03 mm. RME: IM: 6.38 ± 0.85 mm. EP: IM: 4.62± 1.16 mm.
Godoy F., Godoy-Bezerra J. & Rosenblatt A. 2011 34 "Treatment of posterior crossbite comparing 2 appliances: A community-based trial"	Community-based trial	To compare the efficiency of QDH and removable expander appliances in posterior crossbite treatment.	QDH cemented expander: 33 patients (8.00 ± 0.79 yo) EP removable expander: 33 patients (7.82 ± 0.85 yo) Control: 33 patients (8.09 ± 0.81 yo)	Rate of expansion: IC width between the cusp tips. IM width between the center tips.	QDH: Maxilla: IM: 5.70 ± 2.31 mm; IC: 3.48 ± 2.24 mm. Mandible: IM: 0.46 ± 1.2 mm; IC: -0.21 ± 0.92 mm. EP Maxilla: IM: 4.46 ± 2.22 mm; IC: 1.80 ± 2.96 mm. Mandible: IM: -0,12 ± 1,36 mm; IC: 0.28 ± 1.51 mm.
Petrén S., Bjerklin K. & Bondemark L. 2011 19 "Stability of unilateral posterior crossbite in themixed dentition: a randomized clinical trial with 3-year follow-up"	Randomized controlled trial	To evaluate the stability of unilateral posterior crossbite treatment.	QDH cemented expander 20 patients (average: 9 yo) EP removable expander 20 patients (average: 8.5 yo) Control: 20 patients (average: 8.8 yo)	Rate of expansion: IC maxillary width between the gingival margin and cusp tip. IM maxillary width of the canine and 1st molar.	No significant differences in the expansion movement between appliances for overjet, expansion, and overbite. Maxilla: QDH: IC: 2.7 mm; IM: 4.1 mm. EP: IC: 2.6 mm; IM: 3.8 mm.
Weissheimer A. et al. 2011 20 "Immediate effects of rapid maxilla expansion with Haas-type and hyrax-type expanders: A randomized clinical trial"	Randomized clinical trial	To compare the Haas, and Hyrax expanders effects using CBCT.	Haas-type cemented expander 18 patients Hyrax cemented expander 15 patients (overall age: 7.2-14.5 yo)	Rate of expansion: IM maxillary width at the occlusal surface.	No significant differences in the expansion movement between Hyrax and Haas-type expanders even if a better skeletal effect was obtained with Hyrax-type expander. Maxilla: Haas: IM:7.70 ± 0.20 mm. Hyrax: IM: 7.90 ± 0.23 mm.
Wong C.A. et al. 2011 26 "Arch dimension changes from successful slow maxilla expansion of unilateral posterior crossbite"	Retrospective clinical study	To assess the long-term success of SME with Haas, Hyrax or QDH expanders without post-treatment contention.	Haas-type cemented expander: 56 patients Hyrax cemented expander: 26 patients QDH cemented expander: 28 patients (overall average age: 7 yo and 7 months)	Rate of expansion: IC width between cusp tips. IM width: intercentroid. IM angle.	Maxilla: IC: 4.56 ± 0.32 mm; IM: 4.32 ± 0.4 mm. Mandible: IC: -0.19 ± 0.26 mm; IM: 0.27 ± 0.56 mm. IM angle: buccal crown tipping of approximately 4 degrees for both arches during the expansion phase (T1 to T2)
De Rossi M.et al. 2011 12 "Skeletal Alterations Associated with the Use of Bonded Rapid Maxilla Expansion Appliance"	Prospective study	To investigate the skeletal alterations associated with the use of bonded rapid maxilla expansion appliance.	RME: 26 patients (average: 8.7 yo)	Cephalometry analysis.	RME with acrylic bonded appliances did not promote vertical or sagittal deleterious cephalometric changes.
Martina R. et al. 2012 21 "Transverse changes determined by rapid and slow maxilla expansion - a low-dose CT based randomized controlled trial"	Randomized controlled trial	To compare the skeletal modifications induced by RME and SME with CBCT.	SME: 12 patients (10.3 ± 2.5 yo) RME: 14 patients (9.7 ± 1.5 yo)	Rate of expansion: IM maxillary width between the mesiopalatal cusp tips.	No significant differences between SME and RME. Less discomfort and pain with SME. Maxilla: SME IM: 6.3 ± 2.1 mm RME IM: 5.7 ± 1.6 mm

TABLE 4. Summary of the data collected from the systematically revised papers.

Publication data	Study design	Objective	Population & orthodontic intervention	Measurement	Outcomes	
Çörekçi B. & Göyenç 2013 31 "Dentofacial changes from fan-type rapid maxilla expansion vs traditional rapid maxilla expansion in early mixed dentition"	Prospective clinical trial	To compare the dentofacial changes between RME and FRME	FRME: 20 patients (8.96 ± 1.19 yo) RME: 22 patients (8.69 ± 0.66 yo)	IC width between the cusp tips. IM width: intercentroid.	Maxilla: RME IC:34.46 ± 2,81mm; IM: 48.74 ± 2.81mm. FRME IC: 36.34± 2.07mm; IM:46.46± 1.74 mm.	Mandible: RME IC: 26.49 ± 2.11mm; IM: 42.57 ± 3.94mm. FRME IC: 27.36 ± 4.24mm; IM: 42.57 ± 4.76 mm.
Perillo L. et al. 2014 27 "Comparison between rapid and mixed maxilla expansion through an assessment of dento-skeletal effects on posteroanterior cephalometry"	Retrospective study	To compare the dentoskeletal effects between RME and SME	RME: 21 patients (8.8 ± 1.37 yo) MME: 21 patients (8.9 ± 2.34 yo)	IM maxillary width from the most prominent lateral point on the buccal surface of the upper 1st molar.	No significant differences between RME and MME for maxilla expansion and opening of the palatal suture. Maxilla: RME: IM: 6.07 mm. MME: IM: 6.57 mm.	
Melgaço M.A. et al. 2014 22 "Rapid maxilla expansion effects: An alternative assessment method by means of cone-beam tomography"	Randomized clinical trial	To develop and assess a method to evaluate palatal and lingual transverse changes in patients with RME.	Haas cemented expander: 17 patients Hyrax cemented expander : 14 patients	IC mandibular width between the cusp tips. IM maxillary and mandibular widths at the mesiopalatal cusp tip of the 1st molars. IPM maxillary width at the palatal cusp tip of the 1st premolar. IPM mandibular width at the lingual cusp tip of the 1stpremolar.	No significant differences between Haas and Hyrax expanders. Haas Maxilla: IM: 39.80± 2.89 mm; IPM: 29.61 ± 2.43 mm. Mandible: IM: 45.32± 2.99 mm; IPM: 33.27± 1.67 mm. Hyrax Maxilla: IM: 39.79± 1.99 mm; IPM: 28.95 ± 2.84 mm. Mandible: IM: 44.45± 2.87 mm; IPM: 33.65± 3.45 mm.	
Grassia V. et al. 2015 28 "Comparison between rapid and mixed maxilla expansion through an assessment of arch changes on dental casts "	Retrospective study	To compare model cast's patients treated with RME or MME.	RME: 21 patients (8.8 ± 1.37 yo) MME: 21 patients (8.9 ± 2.34 yo)	Rate of expansion: IC width: intercentroid. IM width: Intercentroid. IPM width: intercentroid.	Better transverse superior arch dimension. With RME compared to MME. RME: Maxilla: IC: 4.3 mm; IM: 8.8 mm; IMP1: 6.8 mm; IPM2: 7.3 mm. Mandible: IC: 0.85 mm; IM: 1.5 mm; IMP1: 0.8mm; IMP2: 1.17 mm. MME: Maxilla: IC: 3.7 mm; IM: 8.7 mm; IMP1: 7.3 mm; IPM2: 6.9 mm. Mandible: IC: 1.13 mm; IM: 2.09 mm; IMP1: 1.91mm; IMP2: 2.36 mm	
Mutinelli S. &Cozzani M. 2015 30 "Anchorage onto deciduous teeth: effectiveness of early rapid maxilla expansion in increasing dental arch dimension and improving anterior crowding"	Retrospective study	To assess the effectiveness of early RME with deciduous teeth anchorage.	20 patients (overall average age: 7 yo and 1 month)	Rate of expansion: IC width: inter cusp tip. IM width: inter mesiopalatal cusp tip.	Anchorage onto deciduous teeth allows better arch expansion than anchorage onto permanent teeth. RME: Maxilla: IC: 6.4 mm; IM: 4.8 mm.	
Mohan C.N. et al. 2016 32 "Long-term stability of rapid palatal expansion in the mixed dentition vs the permanent dentition"	Prospective study	To compare the stability of the expansion treatment in mixed or permanent dentition.	54 minor patients at the beginning of the treatment	IM maxillary width between the mesiobuccal cusp tips of the1st molars.	No significant differences were found for long-term IM width stability in patients treated with palatal expansion with mixed vs permanent dentition. Maxilla: IM with mixed dentition: 52.35± 0.45mm; IM with permanent dentition: 52.79± 0.52 mm.	
Pereira J. et al. 2017 35 "Evaluation of the rapid and slow maxilla expansion using cone-beam computed tomography: a randomized clinical trial"	Randomized clinical trial	To evaluate the skeletal and dental alterations after RME or SME with Haas expander.	RME: 21 patients (average: 8.43 yo) SME : 16 patients (average: 8.70 yo)	IM maxillary width at the dentoalveolar border of the 1st molars. Magnitude of changes overtime in the transverse relation. Percentage of the amount of transversal increasing related to opening of the screw expander.	More skeletal changes and more molar inclination after RME. No significant differences for transverse expansion between SME and RME. Maxilla RME: IM: 53.58 ± 2.08 mm; Width/Screw opening(%): 62.5%. SME: IM: 52.72 ± 2.61 mm; Width/Screw opening (%): 61.2%.	

TABLE 4. Summary of the data collected from the systematically revised papers.

Publication data	Study design	Objective	Population & orthodontic intervention	Measurement	Outcomes	
Pham V. & Lagravere M.O. 2017 23 "Alveolar bone level changes in maxilla expansion treatments assessed through CBCT"	Randomized clinical trial	To determinate the alveolar bone changes with CBCT.	Bone anchored expander: 21 patients QDH cemented expander: 20 patients Control: 21 patients	Changes in alveolar bone levels through cone-beam computer tomography (AVIZO software).	No significant differences in alveolar bone levels between control group and treated patients.	
Lanteri V. et al. 2018 33 "Maxillary tridimensional changes after slow expansion with leaf expander in a sample of growing patients: a pilot study"	Pilot study	To assess the maxilla 3D changes after slow expansion with leaf expander in growing patients.	10 patients (7.5 ± 0.7 yo)	Rate of expansion: IC maxillary width between the cusp tips. IC mandibular width between the cusp tips. IM maxillary width between the midpoint of the distobuccal and the mesiopalatal cuspids of the 1st upper molars. IM maxillary width between the central points of the occlusal surface of the 2nd upper temporary molars. IM mandibular width at the mid vestibular cuspids of the lower molars.	Posterior crossbite treated in 4 months with Leaf expander. Maxilla: IC: 6.07 ± 0.83 mm; IM: 3.60 ± 0.72 mm; IM (temporary teeth): 6.17 ± 0.78 mm. Mandible: IC: 0.77 ± 0.65 mm; IM: -0.02 ± 1.07 mm.	
Lanteri V. et al. 2018 29 "Comparison between RME, SME and Leaf Expander in growing patients: a retrospective postero-anterior cephalometric study"	Retrospective study	To compare the RME, SME and Leaf Expander in growing patients.	RME: 10 patients (average: 8.9 yo) SME: 10 patients (average: 12.2 yo) LE: 10 patients (average: 7.9 yo)	IM maxillary and mandibular widths between the most prominent lateral points on the buccal surface of the lower 1st molar.	RME: Maxilla: IM: 50.1 ± 5.0mm; Mandible: IM: 68.9 ± 3.7 mm. SME: Maxilla: IM: 51.7 ± 3.5mm; Mandible: IM: 69.7 ± 6.1 mm.	LE: Maxilla IM:63.9 ± 3.7mm; Mandible: IM: 83.0 ± 3.3 mm.
Ribeiro G.L.U. et al. 2020 24 "A preliminary 3-D comparison of rapid and slow maxilla expansion in children"	Randomized clinical trial	To compare 3D models of RME and SME.	RME 16 patients SME 13 patients (overall average age: 8.18 yo)	Rate of expansion: IC maxillary width: inter cusp tips. IM maxillary width: inter mesiopalatal cusp tips.	RME: Maxilla: IM: 6.64 ± 1.95mm; IC: 3.57 ± 2.04 mm.	SME: Maxilla: IM: 4.10 ± 1.66 mm; IC: 2.96 ± 1.35 mm.
Gonçalves et al. 2022 "Efficiency of Invisalign First® to promote expansion movement in mixed dentition: a clinical study" (current study)	Retrospective study	To evaluate the efficiency of the Invisalign First® system on expansion movement in mixed dentition.	SME 24 patients (6 – 12 yo) (aligner's change every 7 days)	Rate of expansion: IC width between the cusp tips in temporary and permanent teeth. IM width between the mesiopalatal cusp tips in temporary and permanent teeth. IPM width between the palatal cup tips of the1st and 2ndpremolars. Movement efficiency.	SME: Maxilla: IC: 3.4 ± 1.7 mm; Efficiency: 63.5 ± 34.3%; IM: 2.8 ± 1,5 mm; Efficiency: 61.1 ± 31.9%;	Mandibula: IC: 1.4 ± 1.3 mm; Efficiency: 53.2 ± 32.7%; IM: 2.0 ± 1.8 mm; Efficiency: 66.8 ± 75.7%.

Abbreviations: SME: slow maxillary expansion; RME: rapid maxillary expansion; yo: years old; IC: intercanine; IM: intermolar; EP: expansion plate; QDH: quadrihelix; FMRE: fan-type rapid maxillary expansion; MME: mixed maxillary expansion; IPM: interpremolar; CBCT: cone beam computed tomography; LE: leaf expander.

TABLE 4. Summary of the data collected from the systematically revised papers.

Systematic literature review

The initial literature search identified a total of 1743 articles, of which 20 were selected. Considering the current retrospective study, 21 papers were analysed in terms of expansion-related metrics. The article selection process is depicted in the PRISMA flowchart [Moher et al., 2009] (Fig. 5).

Regarding their study design, we found nine randomised clinical trials (45%) [Ramoglu and Sari, 2010; Weyrich, Noss and Lisson, 2010; Petrén, Bjerklin and Bondemark, 2011; Weissheimer et al., 2011; Martina et al., 2012; Melgaço et al., 2014; Pham and Lagravère, 2017; Ribeiro et al., 2020], six retrospective studies (30%) [Huynh et al., 2009; Wong et al., 2011; Perillo et al., 2014; Grassia et al., 2015; Mutinelli et al., 2015; Lanteri, Cossellu, et al., 2018], three prospective studies (15%) [de Rossi, de Rossi and Abrão, 2011; Çörekçi and Göyenç, 2013; Mohan et al., 2016], one pilot study (5%) [Lanteri, Gianolio, et al., 2018], and finally one community-based trial (5%) [Godoy, Godoy-Bezerra and Rosenblatt, 2011]. From the content analysis of the articles selected for this integrative systematic review, two study focuses were identified: the comparison of different types of appliances (e.g., Haas, Hyrax, removable appliances)

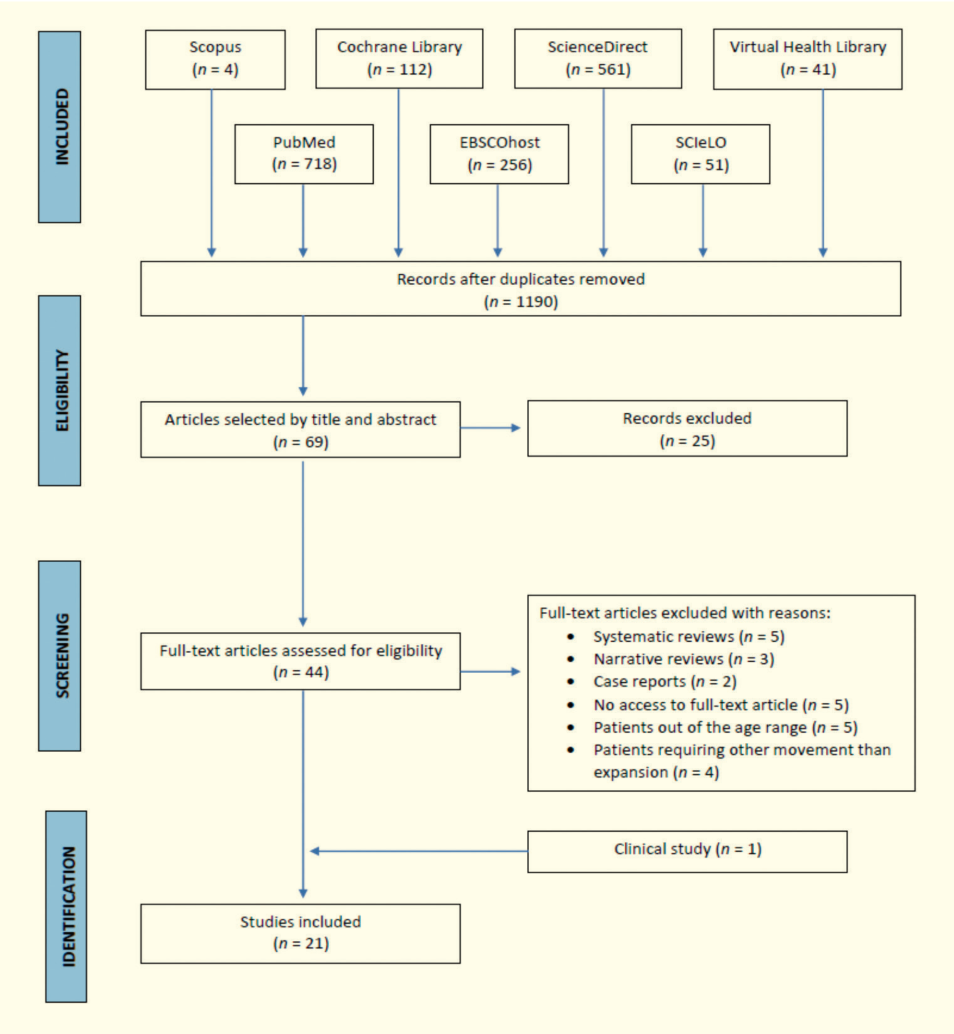

FIG. 5 Flowchart of the study selection using PRISMA guidelines.

[Weyrich, Noss and Lisson, 2010; de Rossi, de Rossi and Abrão, 2011; Godoy, Godoy-Bezerra and Rosenblatt, 2011; Petrén, Bjerklin and Bondemark, 2011; Weissheimer et al., 2011; Wong et al., 2011; Melgaço et al., 2014; Pham and Lagravère, 2017; Lanteri, Gianolio, et al., 2018], and the comparison of therapeutic approaches, as SME or RME [Ramoglu and Sari, 2010; Martina et al., 2012; Çörekçi and Göyenç, 2013; Perillo et al., 2014; Grassia et al., 2015; Mutinelli et al., 2015; Mohan et al., 2016; Pereira et al., 2017; Lanteri, Gianolio, et al., 2018; Ribeiro et al., 2020].

The 20 selected from the literature databases were evaluated in full, and the data was extracted and organised Table 6. This table is structured as follows: publication data (i.e., name of the first author, year of publication and title), study design, objective, population under study, type of orthodontic appliance used, measurement performed, and the results obtained regarding the effectiveness of the proposed treatments.

Moreover, a methodological quality assessment of the included studies was performed (full data on Supplementary Materials). For randomised clinical trials, RoB 2.0 tool was used. The most problematic bias domains were the lack of random sequence generation [Ramoglu and Sari, 2010; Pereira et al., 2017], blinding of participants and personnel [Ramoglu and Sari, 2010; Weyrich, Noss and Lisson, 2010; Weissheimer et al., 2011], and selective reporting [Petrén, Bjerklin and Bondemark, 2011; Pham and Lagravère, 2017)]. For non-randomised trials, ROBINS-I approach was implemented, and considerable bias due to missing data [Godoy, Godoy-Bezerra and Rosenblatt, 2011; Perillo et al., 2014; Grassia et al., 2015; Mutinelli et al., 2015; Lanteri, Cossellu, et al., 2018)], bias in measurements of outcome [Huynh et al., 2009; de Rossi, de Rossi and Abrão, 2011; Godoy, Godoy-Bezerra and Rosenblatt, 2011; Wong et al., 2011; Mutinelli et al., 2015; Mohan et al., 2016; Lanteri, Cossellu, et al., 2018; Lanteri, Gianolio, et al., 2018], and bias in selection of reported results [Huynh et al., 2009; de Rossi, de Rossi and Abrão, 2011; Wong et al., 2011; Çörekçi and Göyenç, 2013; Mutinelli et al., 2015; Mohan et al., 2016; Lanteri, Gianolio, et al., 2018].

Discussion

To critically discuss the present clinical data based on the current knowledge on maxillary expansion in children with malocclusions, we performed a strict integrative and systematic literature review on recent evidence on the efficiency and the amount of movement promoted by alternative expansion methods in children with temporary dentition and adolescents with mixed dentition who need interventional maxillary expansion treatment with removable or fixed expanders. Thus, the results obtained here using the Invisalign First® system were

Metrics	N	t	p-value
Predicted movement (maxillary vs mandibular arches)	12	2.334	0.716
Achieved movement (maxillary vs mandibular arches)	12	1.765	0.286
Difference between predicted and achieved movements (maxillary vs mandibular arches)	12	2.273	0.913
Efficiency (maxillary vs mandibular arches)	12	0.468	0.142
Predicted vs Achieved movements (maxillary arch)	6	4.136	0.272
Predicted vs Achieved movements (mandibular arch)	6	1.580	0.994

TABLE 5. Statistical analysis of the differences between the maxillary and mandibular arches, including the initial ClinCheck®-predicted movements, the real achieved movements in the end of the study, the difference between these two, and the efficiency percentages, using the t- student test for independent samples. Statistical differences between predicted and achieved movements within the maxillary and mandibular arches were also assessed using the t-student test for independent samples.

compared with those from publications using different expanders: fixed coil-spring appliances, conventional removable expanders, or Invisalign® orthodontic systems, and significant discrepancies were comprehensively discussed.

Removable vs fixed orthodontic appliances

The Invisalign First® system is typically programmed to produce tooth movement of 0.15 to 0.25 mm per aligner that must be changed every week [Houle et al., 2017]. In the current study, the amount of expansion prescribed for each patient was individually based on measurements of the dentition, as previously described [Muggiano and Quaranta, 2013; Houle et al., 2017; Zhou and Guo, 2020; Lione et al., 2021].

The expansion can be achieved by two therapeutical approaches: rapid maxillary expansion (RME) and slow maxillary expansion (SME). In the case of RME, the amount of expansion usually fluctuates in growing children from about 0.25 to 0.5 mm per day over a period of one to four weeks, whereas SME (in which the Invisalign First® is included) is characterised by an average of 0.25-mm expansion per week [Huynh et al., 2009; Martina et al., 2012; Perillo et al., 2014; Grassia et al., 2015; Pereira et al., 2017]. On one hand, RME is indicated whenever an orthopaedical effect is desired for transverse spatial repositioning of the maxilla. On the other hand, SME expanders are usually employed for correcting dentoalveolar constriction or crossbites involving groups of dental elements, whether unilateral or bilateral [de Rossi, de Rossi and Abrão, 2011].

While SME appliances can be fixed or removable, the ones used for the RME are anchored onto the temporary or permanent dentition. In the study by Ribeiro G. et al. (Ribeiro et al., 2020), the authors observed that RME and SME produced less expansion than the 8mm programmed for screw activation (83% and 51% efficiency were achieved for screw opening at the intermolar width level, respectively). Moreover, the study by Weissheimer A. et al. [2011], who studied the effects of RME therapeutical approach using the Haas or Hyrax fixed appliances, the authors reported expansion values of 7.7 and 7.9 mm using the 8mm screw activation at the molar level immediately after RME with Haas (i.e., a dento-muco-supported anchorage device) and Hyrax (i.e., a dento-supported anchorage device). Similarly, Martina R. et al [Martina et al., 2012], who studied the transverse changes obtained by RME and SME in children, concluded that the amount of palatal expansion did not differ significantly between the two groups. These findings are in line with the ones reported by Weissheimer et al. [2011], Melgaço et al. [2014], Pham and Lagravere [2017], and Lanteri et al. [2018], who compared the effects of the Haas, Hyrax and Quadri-helix fixed appliances for both RME or SME therapeutical approaches. Overall, given the absence of significant differences between the efficiency of RME and SME modalities, Martina R. et al. [2012] and Wong CA. et al. [2011] support that SME is preferable to RME, as it reduces the discomfort and pain that patients may experience during treatment [Melgaço et al., 2014].

Furthermore, Petrén, Bjerklin and Bondemark [2011] evaluated the expansion efficiency of the Quadri-helix (i.e., a coil-spring fixed appliance) and removable expanders (both producing SME), and found that the Quadri-helix achieved a greater amount of expansion than a removable expander. Similar results were observed in the study conducted by Weyrich, Noss and Lisson [2010], for which a significant 5.74 mm expansion of the dental arch in the region of the first permanent molars was obtained with fixed appliances, compared to an average expansion of 4.62 mm achieved by removable appliances. This can be explained either by the mechanical force applied by the orthodontic appliances, or by the lack of compliance to the orthodontic treatment (which is probably the main disadvantage of removable appliances).

Overall efficiency of the clinical expansion movement

The Invisalign First® system is a removable appliance using the SME therapeutical approach. Regarding the objective to evaluate the effectiveness of the Invisalign First® system for arch expansion, the data obtained (62.6% ± 18.3% efficiency for maxillary expansion and 61.6% ± 32.1% for mandibular expansion) indicate that Invisalign First® clear aligners are an effective tool to achieve transverse expansion. The results showed an increase in all tooth widths to a greater (for the upper and lower premolars palatal cusp tip) or lesser (for the upper temporary canine and lower temporary first molar) degree, either due to the growth potential, and/or because of the influence of bone metabolism on tooth movement during puberty [Lione et al., 2021]. Patients' compliance and the aligners mean time of use must be considered by the orthodontist as these factors have a great impact on the efficiency of the Invisalign First® aligners [Zhou and Guo, 2020].

In our study, the expansion efficiency increased from the canine to the first molar, which was consistent throughout the analysis of the 24 selected cases of children in mixed dentition. This may be due to differences in root anatomy and cortical bone thickness of the canine region, which is not surprising, since maxillary canines have the longest roots and a tapered crown morphology, which gives little retention to aligners [Charalampakis et al., 2018]. A hypothesis is that the transition phase from the mixed to permanent dentition, with the temporary teeth exfoliation and the radiculogenesis of the permanent teeth, has an impact on the tooth movement that usually coincides with an increase in dental

Supplementary Materials

Supplementary Materials 1. Methodological quality assessment of the reviewed studies.

The assessment of risk of bias in eligible studies was analyzed according to the criteria detailed in the Cochrane Collaboration Handbook. The Risk of bias in randomized trials (RoB 2.0) approach and the Risk of Bias Assessment Tool for Non-Randomized Studies (ROBINS-I) were used to evaluate the randomized and observational studies, respectively.

	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Incomplete outcome data	Selective reporting	Other bias
Ramoglu & Sari (2010)	Moderate	Moderate	Moderate	Low	Low	Low
Weyrich, Noss & Lisson (2010)	Low	Low	Moderate	Low	Low	Low
Petrén, Bjerklin & Bondemark (2011)	Low	Low	Low	Low	Moderate	Low
Weissheimer et al. (2011)	Low	Low	Moderate	Low	Low	Low
Martina et al. (2012)	Low	Low	Low	High	Low	Low
Melgaço et al. (2014)	Low	Low	Low	Low	Low	Low
Pereira et al. (2017)	Moderate	Low	Low	Low	Low	Low
Pham & Lagravere (2017)	Low	Low	Low	Low	Moderate	Low
Ribeiro et al. (2020)	Low	Low	Low	Low	Low	Low

TABLE S1. Risk of bias assessment of the randomized clinical trials included in this review by the RoB 2.0 tool, presented by authors' names and year of the studies with the respective result in each assessment item.

	Bias due to confounding	Bias in selection of participants for study	Bias in measurement of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcome	Bias in selection of reported results
Huynh et al. (2010)	Low	Low	Low	Moderate	Low	Moderate	Moderate
Godoy, Godoy-Bezerra & Rosenblatt (2011)	Low	Low	Low	Low	Moderate	Moderate	Low
Wong et al. (2011)	Low	Low	Low	Low	Low	Moderate	Moderate
De Rossi et al. (2011)	Moderate	Low	Moderate	Moderate	Low	High	Moderate
Çörekçi & Göyenç (2012)	Low	Low	Low	Low	Low	Low	Moderate
Perillo et al. (2014)	Low	Low	Low	Low	Moderate	Low	Low
Grassia et al. (2015)	Low	Low	Moderate	Low	Moderate	Low	Low
Mutinelli & Cozzani (2015)	Low	Low	Low	Low	Moderate	Moderate	Moderate
Mohan et al. (2016)	Low	Low	Low	Moderate	Low	Moderate	Moderate
Lanteri et al. (2018)	Low	Low	Low	Low	Moderate	Moderate	Moderate
Lanteri et al. (2018)	Low	Low	Low	Low	Low	Moderate	Low

TABLE S2. Risk of bias assessment of the clinical case studies by the ROBINS-I tool, presented by the authors' names and year of the studies with the respective result in each evaluation item.

arch width caused by an intense craniofacial growth. Indeed, the age span associated with the modification of the periodontic tissues (with the establishment of the periodontal ligament and the influence of bone metabolism on the movement of teeth during puberty) coincide with the stages of the permanent teeth eruption [Zhou and Guo, 2020].

The lower arch presented an efficiency expansion of 61.6% ± 32.1%. This result may be explained by the fact that the amount of movement requested in the lower arch is usually less than in the upper arch. In the current clinical study, the mean requested lower expansion was 3.5 mm, while a mean upper expansion of 6 mm was expected. We observed an increase in the effectiveness of expansion from the anterior mandibular teeth (52.2% efficiency for the canines) compared to posterior teeth (66.8% efficiency for the first molars). These results could be explained by several factors: i) the transition from mixed to permanent dentition, ii) the differences between temporary and permanent teeth widths, and/or iii) the simultaneous reduction of the material resistance due to the wideness of the upper arch. All these situations have a significant impact on the mandibular expansion [de Rossi, de Rossi and Abrão, 2011; Houle et al., 2017; Lione et al., 2021]. According to Phan and Ling [2007], the highest success of Invisalign First® is obtained when treating non-skeletally constricted maxillary arches by tipping movement, which is typically between 0.1 mm and 5.0 mm per quadrant. In the current retrospective study, all patients presented dentoalveolar malocclusions as crowding, posterior crossbite, anterior crossbite, open bite, deep bite, overjet and Class II div 2, and therefore none of our patients had on-skeletally constricted maxillary arches. Moreover, performing exact comparisons between the present investigation and previous studies is difficult due to variations in clinical protocols, treatment plans, and sample characteristics. The rapid advances in technology pose a risk when comparing the few studies found in the scientific literature. Particularly, since 2013 Invisalign® has come out with a new polymer to manufacture the aligners (i.e., the SmartTrack® material) (Clements et al., 2003; Ali and Miethke, 2012), accompanied by a software improvement, which can cause some inconsistencies among studies. Nevertheless, there is still a lack of scientific evidence showing an improvement in movement efficiency related to the new material.

Importantly, this retrospective study shows that when it comes to planning the expansion with the Clincheck® software, overcorrection needs to be considered [Phan and Ling, 2007; Chisari et al., 2014; Houle et al., 2017; Morales-Burruezo et al., 2020; Zhou and Guo, 2020]. Also, auxiliaries such as crossbite elastics can be used to improve the transverse relationship of the teeth [Phan and Ling, 2007; Kravitz et al., 2009].

Study limitations

As removable expanders, the treatment with Invisalign First® aligners needs to be preceded by an evaluation of potential noncompliance and lack of motivation from the patients to follow the orthodontist's instructions. Again, this is one of the main disadvantages of removable appliances, causing treatment hardships such as more time-consuming process until reaching the intended objectives, or even relapse of the initial malocclusion [Phan and Ling, 2007; de Rossi, de Rossi and Abrão, 2011; Zhou and Guo, 2020].

Moreover, it was not possible to make absolute comparisons between the present research and previous studies due to notable differences in the standardization criteria used in the recruitment and selection of candidates, as well as in the measurements of the different widths and in the applied protocol.

Finally, we can point out that the existence of multiple children in a late phase of mixed dentition implied an extra difficulty for the statistical analysis of the data obtained for some groups of teeth (e.g., maxillary first and second premolars, mandibular permanent canine and permanent first premolars), as scarce cases were available for evaluation.

Conclusion

The main points to highlight regarding the present clinical study and the integrative and systematised review perform for results comparison are the following:

When dentoalveolar expansion is planned with Invisalign First® system, the mean maxillary expansion is 6.0 mm, with an efficiency of 62.6 ± 18.3%. On the other hand, the mean mandibular expansion is 3.5 mm, with an expansion efficiency of 61.6 ± 32.1%;

Generally, the amount of expansion movement predicted by Clincheck® software is higher than the clinically achieved movement;

Graphical analysis of the analysed data suggests that the Invisalign First® system has similar outcomes when compared to conventional removable appliances regarding the efficiency of maxillary expansion (literature data), although the efficiency of conventional fixed appliances may be difficult to match.

Why this paper is important to paediatric dentists?

Invisalign First® is at the technological forefront of orthodontic treatments to apply in children, mainly because: i) it is a removable approach; and ii) fixed appliances are a less comfortable solution as they induce greater pain during activation protocol.

Further investigation using Invisalign First® to produce tooth expansion are needed to improve the understanding of the behaviour of different groups of teeth during the movement, mainly in children with mixed dentition. This would contribute to a more accurate and well-founded response to the structural question of this clinical study.

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