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Efficiency of maxillary expansion with Invisalign First® system:

Clinical study compared to integrative systematic review

Sacha-Gabriel Abraham AYACHE

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Gandra, 25 de maio de 2021

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Trabalho realizado sob a Orientação de Mestre Aline dos Santos Gonçalves

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Comunicação Científica em Congresso na Forma de Póster

Submissão de Resumo e Póster Científico, intitulado: "*Efetividade do Invisalign First® na expansão maxilar*", para apresentação durante o 30º Congresso OMD 2021.

EFETIVIDADE DO INVISALIGN FIRST® NA EXPANSÃO MAXILAR

Ayache S*, Gonçalves A, Pinho T.
Dissertation, Department of Dental Sciences, IUCS, IINFACTS, CESPU

INTRODUÇÃO

A expansão maxilar é um tratamento ortodôntico utilizado frequentemente para a correção da dimensão transversal da maxila em crianças. O sistema Invisalign First® é um tratamento inovador no mundo da ortodontia intercetiva, uma vez que vai ao encontro das necessidades de correções funcionais e estéticas aconselhadas pelo ortodontista, assegurando ao mesmo tempo uma elevada adesão terapêutica. É constituído por uma série de alinhadores transparentes que devem ser mudados a cada 7 dias, para um período de tratamento de 18 meses.

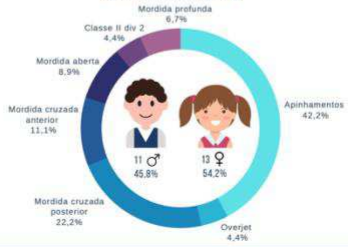
OBJECTIVOS

Abordar a efetividade, ou a capacidade de produzir um efeito, do sistema Invisalign First® na expansão maxilar.

MATERIAIS E MÉTODOS

Foi realizada uma investigação clínica sobre a utilização do Sistema Invisalign First® numa amostra de 24 crianças de 6 aos 12 anos com necessidade de tratamento de expansão maxilar, sem recurso a nenhum tipo de tratamento auxiliar. Os pacientes apresentavam uma dentição mista com os primeiros molares permanentes totalmente erupcionados. Não foi constatada existência de doença sistémica, periodontal ou dentária que pudesse influenciar o movimento dentário.

CARACTERÍSTICAS DA AMOSTRA



CRITÉRIOS DE INCLUSÃO

- Idade entre 6 e 12 anos
- Dentição mista com primeiro molar permanente
- Pacientes tratados exclusivamente com Invisalign First®

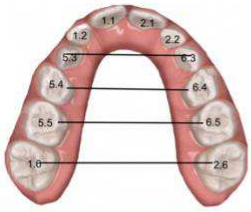
CRITÉRIOS DE EXCLUSÃO

- Doença sistémica que afete movimentos dentários
- Doença periodontal ou dentária
- Síndromes orofaciais
- Tratamento auxiliar com Invisalign First®

ANÁLISE DOS MODELOS

Análise dos modelos:
- Pré-tratamento (T0)
- Tratamento planeado (T1)
- Pós-tratamento (T2)

=> Medições lineares da largura interdentária nas fases (T0), (T1) e (T2) ao nível das cúspides dos caninos permanentes ou decíduos, das cúspides palatinas dos premolares ou molares decíduos e ao nível das cúspides mesiopalatinas dos primeiros molares permanentes.



ANÁLISE ESTATÍSTICA

MAXILAR

Tooth type	N	Predicted	SD	Achieved	SD	Diff P-A	SD	Efficiency	SD
canine	14	5,5	1,9	3,4	1,7	2,1	1,7	63,5%	34,3%
first PM	15	6,6	1,2	4,1	1,2	2,5	1,3	62,1%	17,8%
second PM	20	6,3	0,7	4,0	1,2	2,3	1,0	63,6%	15,5%
first M	24	4,6	0,6	2,8	1,5	1,8	1,4	61,1%	31,9%
TOTAL	73	5,6	1,1	3,5	1,4	2,1	1,3	62,6%	24,9%

MANDIBULAR

Tooth type	N	Predicted	SD	Achieved	SD	Diff P-A	SD	Efficiency	SD
canine	11	2,5	1,7	1,4	1,3	1,2	0,9	53,2%	32,7%
first PM	14	4,5	1,8	2,5	2,3	2,0	1,6	55,0%	57,8%
second PM	16	4,1	1,6	2,5	1,1	1,7	1,3	59,9%	43,8%
first M	24	3,0	1,8	2,0	1,8	1,0	1,7	66,8%	75,7%
TOTAL	65	3,5	1,7	2,1	1,6	1,4	1,4	58,7%	52,5%

RESULTADOS

Foi estatisticamente analisada uma efetividade total da expansão maxilar de 62,6% com uma expansão média prevista de 5,6 mm. Por sua vez, a efetividade total da expansão mandibular foi de 58,7%, com uma média prevista de 3,5 mm. Foi observada uma ligeira diminuição na efetividade dos dentes anteriores da maxila (caninos 63,5%) em comparação com os dentes posteriores (primeiros molares 61,1%). Esta observação foi constante ao longo da análise dos 24 pacientes selecionados para esta investigação. Este resultado pode ser atribuído às variações anatómicas das raízes dos dentes, à espessura do osso cortical, ou uma maior resistência dos tecidos moles da região posterior das bochechas (5). Uma hipótese suplementar é que as forças fornecidas pelo Invisalign First® diminuem devido à resistência do material dos alinhadores (5).

CONCLUSÃO

O Invisalign First® está na vanguarda tecnológica quando se fala de tratamentos ortodônticos removíveis. Relativamente ao objetivo, em relação à avaliação da eficácia do sistema Invisalign First® na expansão maxilar, os dados obtidos indicaram que os alinhadores Invisalign® são uma ferramenta eficaz para alcançar expansão transversal, uma vez que os resultados registados mostraram um aumento significativo de todas as larguras interdentárias em maior ou menor grau.

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Estes últimos cinco anos têm sido de realização, quer a nível pessoal como profissional e finalmente, chegamos ao fim!

Nada disto teria sido possível sem o apoio das pessoas que me são tão especiais;

Aos meus pais queridos que nunca me falharam ou duvidaram de mim, que sempre me apoiaram nas minhas escolhas e me aceitaram como eu sou. Aos meus pais que me deram tudo sem nunca me pedirem nada. Espero que hoje lhes encha o coração de orgulho;

Às minhas irmãs que vivem em Israel, Portugal e França. Obrigado por todo o apoio;

Aos meus avós que me viram crescer e sempre souberam ouvir;

Ao Bruno que entrou na minha vida à velocidade de uma estrela cadente e preencheu o espaço vazio no meu coração;

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A todos os professores que se cruzaram no meu caminho e com os quais tive o prazer de aprender o que sei hoje;

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"Maman, j'entre dans l'avion. Cette fois je n'ai pris qu'un billet aller vers le reste de ma vie. Je t'envoie un message quand j'arrive, comme d'hab' !"

Resumo

Introdução: A expansão maxilar pode ser alcançada através da RME ou SME, utilizando expansores fixos ou removíveis. O Invisalign First® permite a expansão maxilar de uma forma estética, o que não é possível com os expansores tradicionais.

Objetivo: Abordar as diferenças da efetividade entre o Invisalign First® e os aparelhos de expansão maxilar tradicionais.

Materiais e Métodos: Foram selecionados 24 casos para o estudo clínico. As tabelas de movimento dentário foram analisadas na plataforma Invisalign®, tendo em conta os modelos de pré-tratamento (T0) e tratamento planeado (T1) pelo software Clinchek®, tal como os modelos digitais 3D de pós-tratamento (T2), relativamente à largura da arcada dentária e à eficiência da expansão. Foi também realizada uma pesquisa bibliográfica nas bases de dados PubMed, Cochrane Library, ScienceDirect, EBSCOhost, Scopus, SciElo e Virtual Health Library usando as palavras-chave: "tratamento ortodôntico", "mordida cruzada posterior", "técnica de expansão palatina", “discrepância transversal” e "dentição mista". Foram selecionados artigos redigidos em inglês, francês e português, publicados entre 2010 e 2021, tendo sido ao todo 1743 artigos, dos quais foram selecionados 20 artigos.

Resultados: RME ou SME podem ser consideradas duas abordagens terapêuticas para melhorar a dimensão transversal da arcada dentária. O sistema Invisalign First®, para além de fornecer uma excelente estética durante o tratamento, apresenta resultados de efetividade total de expansão maxilar de 62,6% e mandibular de 58,7%. Esses resultados são semelhantes aos dos aparelhos convencionais removíveis no que diz respeito à eficiência da expansão maxilar.

Conclusão: O sistema Invisalign First® apresenta resultados semelhantes aos dos aparelhos removíveis convencionais, no que respeita à eficiência da expansão maxilar. No entanto, não é tão eficiente quando comparado aos resultados obtidos pelos aparelhos cimentados.

Palavras-chave: Tratamento Ortodôntico, Mordida cruzada posterior, Técnica de expansão palatina, Discrepância transversal, Dentição mista.

Abstract

Introduction: Maxillary expansion can be achieved through RME or SME, using either cemented or removable appliances. Invisalign First® allows maxillary expansion and provides aesthetic that traditional expanders cannot.

Objective: To compare the differences in effectiveness between Invisalign First® and traditional expanders.

Materials and Methods: 24 cases were selected for the clinical study. The tooth movement tables on the Invisalign® platform were analysed, considering the pre-treatment (T0) and planned treatment (T1) models by the Clinchek® software, just as post-treatment (T2) 3D digital models, regarding the width of the dental arch and the efficiency of the expansion. At the same time, a literature search was performed in PubMed, Cochrane Library, ScienceDirect, EBSCOhost, Scopus, SciElo and Virtual Health Library using the keywords: "orthodontic treatment", "posterior crossbite", "palatal expansion technique", 'transverse discrepancy" and "mixed dentition". Were collected articles written in English, French and Portuguese, published between 2010 and 2021. 1743 articles were identified and after analysis, 20 were selected.

Results: RME or SME can be considered two effective therapeutic approaches to improve the transverse dimension of the dental arch. The Invisalign First® system, in addition to providing excellent aesthetic during treatment, has total maxillary expansion effectiveness results of 62.6% and mandibular expansion results of 58.7%. These results are similar to those of conventional removable appliances in terms of maxillary expansion efficiency.

Conclusion: The Invisalign First® system provides similar results to conventional removable appliances in terms of maxillary expansion efficiency. However, it is not as efficient when compared to the results obtained by cement-retained appliances.

Keywords: Orthodontic Treatment, Palatal expansion technique, Posterior crossbite, Transverse discrepancy, Mixed dentition.

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LIST OF ABREVIATIONS

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PICOS - Patient, Intervention, Comparison, Outcome, Study design

Mm - Millimeters

Yo - Years old

QDH - Quadri-Helix

EP - Expansion orthodontic removable plate

CBCT - Cone Beam Computed Tomography

NSD - Non-significative difference

SD - Significative difference

SME - Slow Maxillary Expansion

RME - Rapid Maxillary Expansion

M1 - First molar

IC - Intercanine

IM - Intermolar

IPM1 - Inter first premolar

IPM2 - Inter second premolar

1 INTRODUCTION

Maxillary expansion is usually used in cases of true maxillary insufficiency, to correct transverse skeletal and dental discrepancies or to increase the perimeter of the upper arch (1). This can be clinically evidenced by the existence of a unilateral or bilateral posterior crossbite, dental arch narrowing, dental crowding or protrusion (1,2). The prevalence of posterior crossbite is between 8% and 16% (3), in individuals between 7 and 9 years of age, with no gender difference (4). It is defined as an abnormal buccolingual relationship between the maxillary and mandibular teeth when both arches are in maximum intercuspation (4). Maxillary expansion will not only restore adequate width of the dental arches in the mixed dentition but will also increase the available length of the arches and provide additional space for alignment. Furthermore, it is estimated that 25-30% of all orthodontic patients can benefit from maxillary expansion (3).

The transition phase from the mixed dentition to the permanent one usually coincides with an intense growth of the child characterized by orthodontic and orthopaedic changes (5). Dentists and specialists have several treatment options whereby traditional cemented or removable expansion appliances are used.

Nowadays, patients undergoing orthodontic treatment prefer appliances that provide better aesthetic. However, the Invisalign First® system has revolutionized interceptive orthodontic treatments in that it is a removable appliance made of a transparent material that can provide aesthetic and results. It consists of a series of aligners exchanged every 7 days for a treatment duration of 18 months.

Thus, the aim of this clinical study compared to an integrative systematic review is to answer the following question: How effective are Invisalign First® orthodontic aligners compared with traditional expanders in promoting tooth expansion movement?

2 MATERIALS AND METHODS

2.1 Participants and design of the clinical study

To carry out the clinical investigation, digital models of 24 patients treated between 2018 and 2021 were sequentially selected to this study. The mixed-gender study sample of child patients undergoing orthodontic treatment exclusively with Invisalign First® system, had to have at last 6 years old and the first permanent molars fully erupted. All patients were treated by Professora Doutora Teresa Pinho in her private orthodontic practice in Porto, Portugal. The study was approved by the Ethics Committee of the Instituto Universitário de Ciências da Saúde.

The 3D digital models of pre-treatment (T0) and planned-treatment (T1) by the Clincheck® software, just as the post-treatment models (T2) were collected. Upper dental arch width and expansion efficiency (expansion achieved/expansion predicted) were measured and calculated.

All patients met the following inclusion criteria:

- Age between 6 and 12 years old;
- Mixed dentition with first molars fully erupted;
- Good tooth contour, with sufficient height of clinical crowns;

The exclusion criteria were as follow:

- Systematic disease affecting tooth movement;
- Orofacial malformation syndromes;
- Periodontal and dental disease;
- Auxiliary treatment during the arch expansion stage.

The tooth movement tables on the Invisalign® platform were analysed, considering the pre-treatment (T0) and planned treatment (T1) models by the Clinchek® software, just as post-treatment (T2) 3D digital models, regarding the width of the dental arch and the efficiency of the expansion. Interdental widths linear measurements at (T0), (T1) and (T2) stages were recorded, including deciduous or permanent intercanine widths from the cusps tip, inter premolar widths from the palatal cusps tip of upper first premolar and second premolar or first deciduous molar and second deciduous molar, and intermolar widths from the mesopalatal cusps tip of the upper first molars (**Figure 1**).

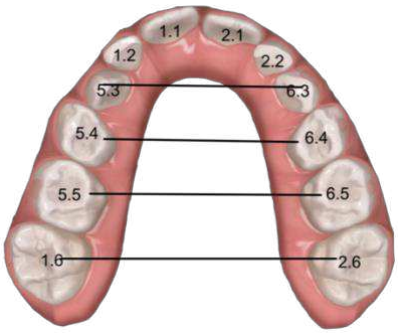

Figure 1 - Interdental widths linear measurements by Clincheck® software

For the purpose of our study, tooth expansion was considered only when there was no transition from deciduous to permanent teeth at the initial and final time treatment, to be compared with the data collected from the selected articles of this integrative systematic review. The expansion efficiency was calculated as a percentage with the following formula (6):

$$\frac{achieved\ expansion\ movemement(T2-T0)}{predicted\ expansion\ movement(T1-T0)}$$

2.2 Selection criteria of the articles

The review protocol used was the one described in the PRISMA recommendations (PRISMA Statement), using the PRISMA checklist available at http://www.prisma-statement.org/PRISMAStatement/Checklist and the PRISMA Flowchart available at http://www.prisma-statement.org/PRISMAStatement/FlowDiagram.

The articles included in this systematic review were selected according to the below criteria (**Table 1**), following the PICOS strategy:

Table 1 - PICOS strategy

Patient	Clinical studies of human children or adolescents with temporary or mixed dentition who need interventional maxillary expansion treatment.
Intervention	Maxillary expansion treatment with removable or fixed expanders.
Comparison	Control group of children not treated or treated with other expansion methods. Control group with normal occlusion were considered invalid.
Outcome	Measurement of maxillary expansion at bone and dental levels. Correction of posterior crossbite or other malocclusions involved.
Study design	Prospective and retrospective clinical studies, community-based trial, randomized clinical trial.

Inclusion Criteria

- Articles published from 2010 to January 2021 to focus our goal on identifying more recent evidence about conventional expanders to be compared at the result of our clinical study;
- English, French and Portuguese languages;
- Availability: full articles that relate to the topic and are not restricted;
- Articles whose study refers to patients with mixed dentition;
- Studies performed in humans;
- Prospective and retrospective clinical studies, community-based trial, randomized clinical trial;

Exclusion criteria

- Abstract does not fit the topic;
- Full reading did not provide revealing information;
- Systematic reviews, case reports, thesis and dissertations;
- Articles in languages other than English, French or Portuguese;
- Articles not available in the database referred in full text;
- Articles before 2010.

2.3 Data sources

A literature research was performed in the following databases: PubMed (via National Library of Medicine), Cochrane Library, ScienceDirect, EBSCOHost, SciElo, Virtual Health Library and Scopus from 2010 to January 2021 using the following keywords: "orthodontic treatment", "posterior crossbite", "palatal expansion technique", “transverse discrepancy”, "mixed dentition" and the related MeSH terms, which can be found in the titles and abstracts.

The search strategies are detailed in **Table 2**.

Table 2 - Search strategy

Databases	Search strategy	Total articles	Selected articles
PubMed	(orthodontic appliances, fixed OR orthodontic appliances, removable OR orthodontic treatment OR orthodontics, corrective OR orthodontics, interceptive OR Haas OR Hyrax OR quad-helix) AND (maxillary expansion OR maxillary disjunction OR palatal expansion technique OR palatal expansion OR palatal disjunction OR rapid maxillary expansion OR RME OR slow maxillary expansion OR SME OR RPE OR SPE OR posterior crossbite OR transverse discrepancy OR constricted maxilla) AND (stability OR effectiveness OR outcome) AND (mixed dentition OR deciduous dentition OR primary teeth OR primary dentition OR transitional dentition OR child OR children)	718	34
Cochrane library Trials	(orthodontic appliances, fixed OR orthodontic appliances, removable OR orthodontic treatment OR orthodontics, corrective OR orthodontics, interceptive OR Haas OR Hyrax OR quad-helix) AND (maxillary expansion OR maxillary disjunction OR palatal expansion technique OR palatal expansion OR palatal disjunction OR rapid maxillary expansion OR RME OR slow maxillary expansion OR SME OR RPE OR SPE OR posterior crossbite OR transverse discrepancy OR constricted maxilla) AND (stability OR effectiveness OR outcome) AND (mixed dentition OR deciduous dentition OR primary teeth OR primary dentition OR transitional dentition OR child OR children)	112	11

EBSCOhost	(orthodontic appliances, fixed OR orthodontic appliances, removable OR orthodontic treatment OR orthodontics, corrective OR orthodontics, interceptive OR Haas OR Hyrax OR quad-helix) AND (maxillary expansion OR maxillary disjunction OR palatal expansion technique OR palatal expansion OR palatal disjunction OR rapid maxillary expansion OR RME OR slow maxillary expansion OR SME OR RPE OR SPE OR posterior crossbite OR transverse discrepancy OR constricted maxilla) AND (stability OR effectiveness OR outcome) AND (mixed dentition OR deciduous dentition OR primary teeth OR primary dentition OR transitional dentition OR child OR children)	256	17
ScienceDirect	(Orthodontic appliances OR orthodontic treatment) AND (maxillary expansion OR "palatal expansion technique" OR posterior crossbite) AND (stability OR effectiveness) AND (mixed dentition OR child)	561	17
SciElo	Palatal expansion technique	51	4
Virtual Health Library	(orthodontic appliances, fixed OR orthodontic appliances, removable OR orthodontic treatment OR orthodontics, corrective OR orthodontics, interceptive OR Haas OR Hyrax OR quad-helix) AND (maxillary expansion OR maxillary disjunction OR palatal expansion technique OR palatal expansion OR palatal disjunction OR rapid maxillary expansion OR RME OR slow maxillary expansion OR SME OR RPE OR SPE OR posterior crossbite OR transverse discrepancy OR constricted maxilla) AND (stability OR effectiveness OR outcome) AND (mixed dentition OR deciduous dentition OR primary teeth OR primary dentition OR transitional dentition OR child OR children)	41	11
Scopus	(orthodontic appliances, fixed OR orthodontic appliances, removable OR orthodontic treatment OR orthodontics, corrective OR orthodontics, interceptive OR Haas OR Hyrax OR quad-helix) AND (maxillary expansion OR maxillary disjunction OR palatal expansion technique OR palatal expansion OR palatal disjunction OR rapid maxillary expansion OR RME OR slow maxillary expansion OR SME OR RPE OR SPE OR posterior crossbite OR transverse discrepancy OR constricted maxilla) AND (stability OR effectiveness OR outcome) AND (mixed dentition OR deciduous dentition OR primary teeth OR	4	0

	primary dentition OR transitional dentition OR child OR children)		
Manual search	Cabreba CA. Ortodontia clínica 2ª edição. Capítulo 13: expansão do arco dentário superior. 432-460.	-	1

2.4 Selection of the articles

Step I - Seven electronic databases were searched from 2010 to January 2021. Advanced searches were performed in PubMed, Cochrane Library, ESBCOhost, ScienceDirect, SciElo, Virtual Health Library and Scopus using the keywords: "orthodontic appliance", "palatal expansion technique", "transverse discrepancy", "mixed dentition", "outcome". Two filters were applied in the search, the filter of the range of years (2010 to 2021) to collect recent information and the filter of publications in English, Portuguese and French. Duplicate articles were removed using the Mendeley citation tool. The title and abstract of identified and potentially relevant articles were subjected to a preliminary evaluation. Systematic reviews and case reports, articles in languages other than the selected ones, and articles not available in full were then excluded.

Step II - Potentially eligible articles were reviewed and read in their entirety in order to select those that best met the objective of this paper.

Step III - The articles were evaluated in full, and the data were extracted and organized into a table. This was divided into the names of the authors of each study, the year of publication, the main objective, the type of study, and the main results found.

The following information were extracted from each article and organized in table form: First author's name; Year of publication; Study design; Title of article; Objectives; Age and number of participants; Main outcomes (measurements and efficiency).

3 RESULTS

3.1 Characteristics of the clinical study sample

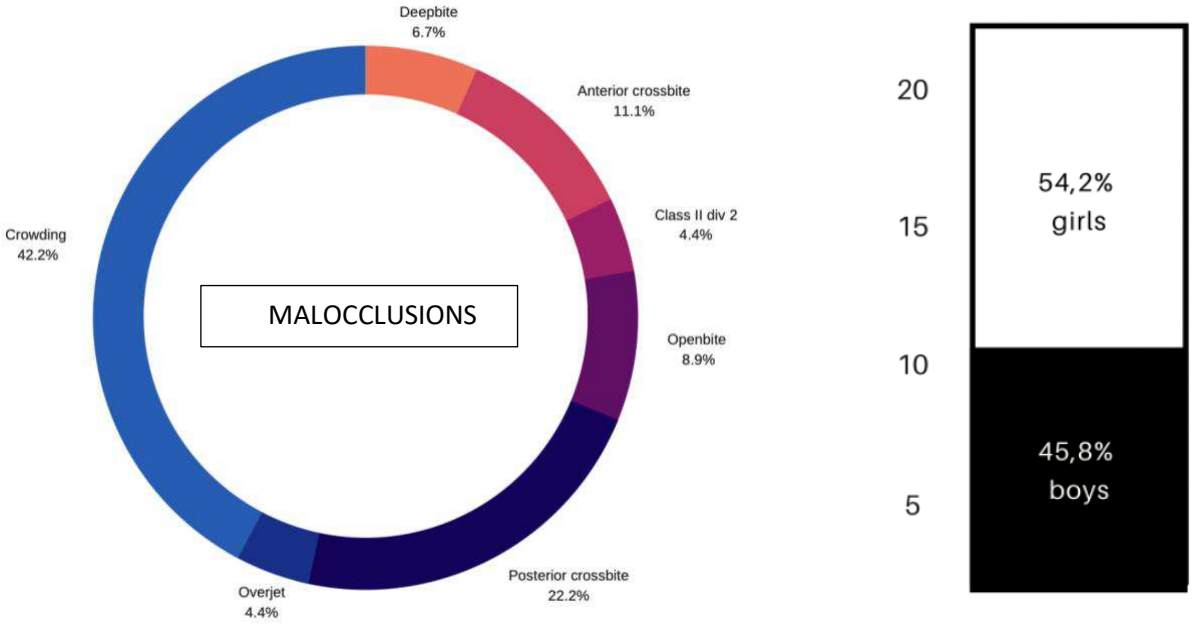

Figure 2 - Characteristics of the clinical study sample

Of the 24 selected cases, the sample distribution can be considered equivalent with 11 boys (45,8%) and 13 girls (54,2%). Each patient can present different types of malocclusion. All the sample's characteristics are presented in **Figure 2**.

Regarding the distribution of the malocclusions, 19 cases presented crowding (42,2%), 10 cases presented posterior crossbite (22,2%), 5 cases presented anterior crossbite (11,1%), 4 cases presented open bite (8,9%), 3 cases presented deep bite (6,7%) and finally 2 cases presented overjet or Class II division 2 (4,4%).

3.2 Results of the clinical study

The results (in mm) of this clinical study showed that Invisalign First® aligners can achieve arch expansion, as the expansion efficiencies were 63,5%, at the canine cusps tip, 62,1% at the first premolar palatal cusps tip, 63,6% at the second premolar palatal cusps tip and 61,1% at the mesolingual cusps tip of the first molar, of the predicted

amount of expansion by the Clincheck® software. The total effectiveness of maxillary expansion was 62,6% with the Invisalign First® aligners. In turn, the total effectiveness of mandibular expansion was 58,7% with a predicted mean expansion of 3.5 mm by the Clincheck® software and a clinical achieved expansion of 2,1mm (**Table 3**).

Table 3 - Efficiency of maxillary and mandibular expansion movement with Invisalign First®

canine	14	5,5	1,9	3,4	1,7	2,1	1,7	63,5%	34,3%
first PM	15	6,6	1,2	4,1	1,2	2,5	1,3	62,1%	17,8%
second PM	20	6,3	0,7	4,0	1,2	2,3	1,0	63,6%	15,5%
first M	24	4,6	0,6	2,8	1,5	1,8	1,4	61,1%	31,9%
TOTAL	73	5,6	1,1	3,5	1,4	2,1	1,3	62,6%	24,9%

MANDIBULAR

Tooth type	**N**	**Predicted**	**SD**	**Achieved**	**SD**	**Diff P-A**	**SD**	**Efficiency**	**SD**
canine	11	2,5	1,7	1,4	1,3	1,2	0,9	53,2%	32,7%
first PM	14	4,5	1,8	2,5	2,3	2,0	1,6	55,0%	57,8%
second PM	16	4,1	1,6	2,5	1,1	1,7	1,3	59,9%	43,8%
first M	24	3,0	1,8	2,0	1,8	1,0	1,7	66,8%	75,7%
TOTAL	65	3,5	1,7	2,1	1,6	1,4	1,4	58,7%	52,5%

3.3 Selection of the articles

Step I - Database results

The literature search identified a total of 1743 articles. After removing the duplicates, 1190 articles remained. After reading the titles and abstracts, 69 articles were selected for further analysis. Of the 69 articles, 24 were excluded because they did not meet the inclusion criteria. Finally, 45 articles were included for review.

Step II - Articles reviewed

The 45 articles were individually reviewed for quality, of which 20 were selected.

Step III - Articles included

At this stage, the articles selected for inclusion in this systematic review were analysed. Of these 45 articles, 25 were excluded for not providing relevant information.

Finally, 20 articles were included in this systematic review. The article selection process is shown in the PRISMA flow-chart (**Figure 3**).

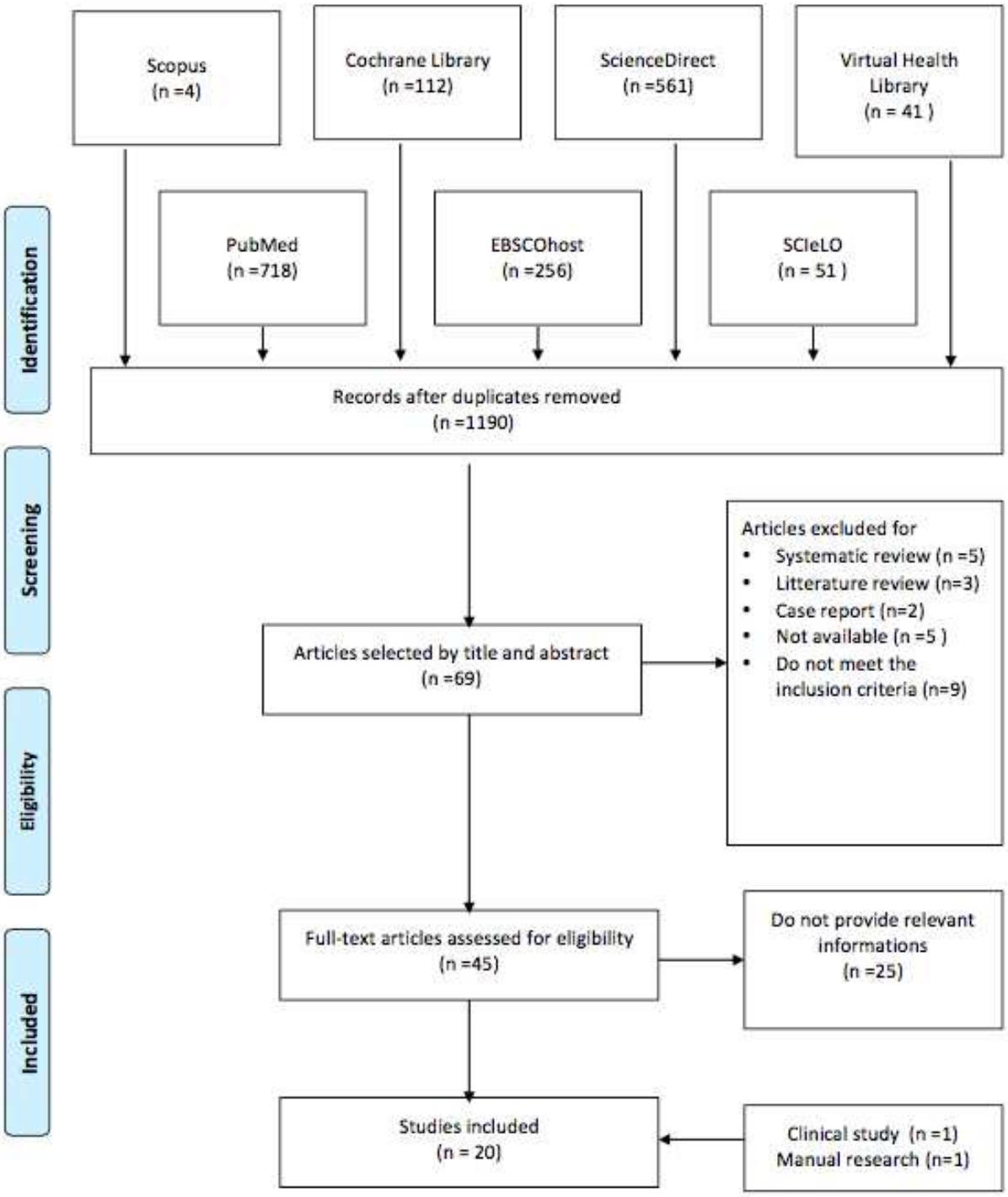

Figure 3 - PRISMA flow-chart

3.4 Characteristics of the selected articles

Years of publication

Regarding the period of publication, the year 2011 recorded the highest number of articles on the topic in question, presenting 5 articles (25%), the year 2010 with 3 articles (15%), the year 2014, 2015, 2016 and 2017 with 2 articles each (10%) and finally the year 2012, 2013, 2018 and 2020 with 1 article each (5%). Articles from the years 2019 and 2021 were not selected. **Figure 4** shows the distribution regarding the years of publication.

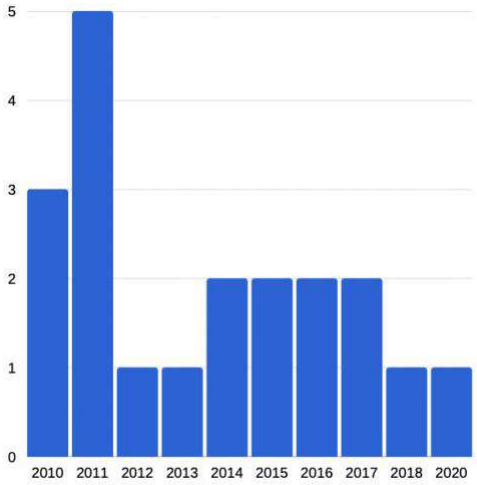

Figure 4 - Years of publication

Design study

As for the type of studies of the articles evaluated, 9 are randomized clinical trials (45%), 6 are retrospective studies (30%), 3 are prospective studies (15%), 1 is a pilot study (5%) and finally 1 is a community-based trial (5%). **Figure 5** shows the distribution regarding the design of the selected studies.

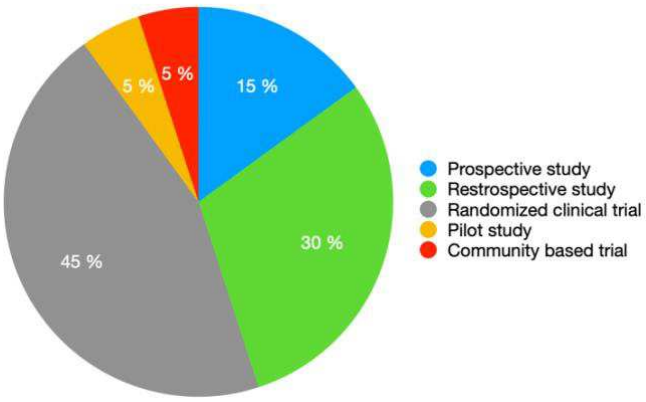

Figure 5 - Design study

From the content analysis of the articles selected for this integrative systematic review, 2 study categories resulted: articles comparing different types of appliances and articles comparing different therapeutic approaches as SME or RME. **Figure 6** shows the distribution percentage regarding the objectives of the selected studies.

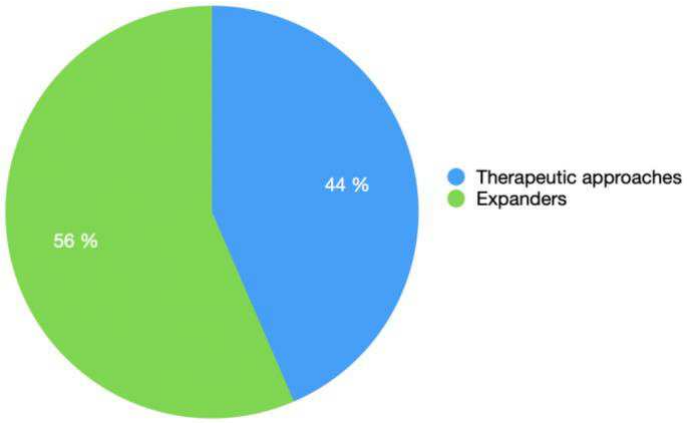

Figure 6 - Objectives of the studies

3.5 Data collection process

Table 4 structures the information obtained from the clinical study about the Invisalign First® system. **Table 5** structures the information obtained from the articles included in this integrative systematic review and is organized as follows: authors' names and years of publication of the articles, type of studies, titles of the articles and objectives, number of participants and age range, type of used appliance and the results obtained regarding the effectiveness of the proposed treatments.

Table 4 - Data and outcomes from clinical study

Investigators **Year of the investigation**	**Design study**	**Objective**	**Appliance** **Range age** **Nº of participants**	**Measurement**	**Outcomes**
Ayache S. **Pinho T.** **2021**	Retrospective study	Evaluate the efficiency of the Invisalign First® system on expansion movement in mixed dentition	Invisalign First® aligners changed every 7 days 24 cases selected From 6 to 12 years old	Interdental width: deciduous or permanent IC width from the cusps tip IPM1/IPM2 widths from the palatal cusps tip or first deciduous molar and second deciduous molar IM width from the mesopalatal cusps tip of the upper first molars	<u>Maxilla:</u> IC: 3,4± 1,7 Efficiency : 63,5% ± 34,3% IM: 2,8± 1,5 Efficiency : 61,1% ± 31,9% <u>Mandibula:</u> IC: 1,4 ± 1,3 Efficiency: 53,2% ± 32,7% IM: 2,0 ± 1,8 Efficiency: 66,8%± 75,7%

Table 5 - Data and outcomes from articles

Author and year of publication	**Design study**	**Title**	**Objective**	**Appliances** **Range age** **Nº of participants**	**Measurement**	**Outcomes**
Ramoglu S.I. **2010** (22)	Randomized clinical trial	"Maxillary expansion in the mixed dentition: rapid or semi-rapid?"	Evaluate the effects of RME and SRME expansion	<u>SRME :</u> 18 patients 8.63±1.09 yo <u>RME :</u>	Cephalometric study Dental cast IC- cusp tip to cusp tip IM- sulcus to sulcus	NSD dentofacial structures for transverse, sagittal and vertical plans <u>Maxilla:</u> IC: 4,77±1,53 IM: 5,11±1,81

				17 patients 8.78±1.61 yo		Mandible: IC: 0,38±0,43 IM: 0,12±0,32
Huynh T. **2010** (8)	Retrospective study	« Treatment response and stability of slow maxillary expansion using Haas, hyrax, and quad-helix appliances: A retrospective study »	Stability of SME using Haas, Hyrax and QDH appliances	Haas : 74 patients Hyrax: 41 patients QDH : 45 patients Age- 8 yo	Dental casts Maxillary width	NSD: Haas, Hyrax or QDH Maxillary width: 3,89
Weyrich C. **2010** (24)	Randomized clinical trial	"Comparison of a Modified RME Appliance with Other Appliances for Transverse Maxillary Expansion»	Comparison of a Modified RME Appliance with Other Appliances for Transverse Maxillary Expansion	Mod RME : 20 patients 8.77±0.57yo RME : 10 patients EP: 10 patients	Dental casts Unspecified Pre, during and post treatment dental casts analysis Maxillary Width	NSD: RME and mod. RME SD: RME/EP EP: 3,59±1,07
Godoy F. **2011** (25)	Community-based trial	"Treatment of posterior crossbite comparing 2 appliances: A community-based trial"	Comparison efficiency between QDH and removable expander appliances in posterior	QDH: 33 patients 8±0.79 yo EP: 33 patients 7.82±0.85 yo	Dental casts IC width from cusp tip left to right IM width from pit center left to right	Maxillary: QDH-IM:5,70±2,31 IC:3,48±2,24 EP-IM :4,46±2,22 IC:1,80±2,96 Mandibular:

			crossbite treatment	Control: 33 patients 8.09±0.81 yo		QDH-IM:0,46±1,2 IC:-0,21±0,92 EP-IM :-0,12±1,36 IC:0,28±1,51
Petren S. **2011** (23)	Randomized controlled trial	"Stability of unilateral posterior crossbite in the mixed dentition: a randomized clinical trial with 3-year follow-up"	Evaluate the stability of unilateral posterior crossbite treatment	QDH 20 patients ±9 yo EP 20 patients 8.5 yo Control: 20 patients 8.8 yo	Dental casts Gingival margin and cusp tip of C and M1	NSD between appliances for overjet, expansion and overbite QDH: IC= 2,7 IM= 4,1 EP: IC= 2,6 IM= 3,8
Weissheimer A. **2011** (14)	Randomized clinical trial	"Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: A randomized clinical trial"	Comparison of Haas, and Hyrax expanders effects using CBCT	Haas 18 patients Hyrax 15 patients 7.2-14.5 yo	CBCT Skeletal, dental and alveolar analysis Points formed by the intersection of a straight line, that superimpose the long axis of the root canal	NSD between Hyrax and Haas-type expanders even if a better skeletal effect was obtained with Hyrax-type expander Maxillary width: Haas: 7,70± 0,20 Hyrax: 7,90±0,23

					of first permanent molar palatine root, with the occlusal surface on the right and left sides, respectively	
Wong C.A. **2011** (20)	Retrospective clinical study	"Arch dimension changes from successful slow maxillary expansion of unilateral posterior crossbite"	Long term success of SME with Hass, Hyrax or QDH expanders without post-treatment contention	<u>Haas-type expander:</u> 56 patients <u>Hyrax:</u> 26 patients <u>QDH:</u> 28 patients 7yo and 7months	<u>Dental casts:</u> Arch circumference Intercanine width – cusp tip to cusp tip Intermolar width – intercentroid point Maxillary width Intermolar angle	<u>Maxilla:</u> IC: 4,56±0,32 IM: 4,32±0,4 <u>Mandible:</u> IC: -0,19±0,26 IM 0,27±0,56
De Rossi M. **2011** (28)	Prospective study	"Skeletal Alterations Associated with the Use of Bonded Rapid Maxillary Expansion Appliance "	Skeletal Alterations Associated with the Use of Bonded Rapid Maxillary Expansion Appliance	<u>RME:</u> 26 patients 8.7 yo	Cephalometric study Unspecified	RME with acrylic bonded appliances didn't promote vertical or sagittal deleterious cephalometric changes
Martina R. **2012** (7)	Randomized controlled trial	"Transverse changes determined by rapid and slow maxillary	Comparison of skeletal modifications	<u>SME :</u> 12 patients	CBCT	NSD between SME and RME Less discomfort and pain with SME

		expansion- a low-dose CT based randomized controlled trial"	between RME and SME with CBCT	10.3±2.5 yo RME : 14 patients 9.7±1.5 yo	Intermolar distance inter mesopalatal cusp tip	SME-IM: 6,3±2,1 RME-IM: 5,7±1,6
Çorekçi B. **2013** (27)	Prospective clinical trial	« Dentofacial changes from fan-type rapid maxillary expansion vs traditional rapid maxillary expansion in early mixed dentition »	Comparison of dentofacial changes between RME and FRME	FRME : 20 patients 8.96±1.19 yo RME : 22 patients 8.69±0.66 yo	Cephalometric study Dental cast IC- inter cusp tip IM – intercentroid point	Nasal cavity and intermolar width > RME Maxilla: IC:5,13±2,02 IM: 5,43±2,54 Mandible: IC: 0,52±0,92 IM: 0,32±1,22
Perillo L. **2014** (10)	Retrospective study	"Comparison between rapid and mixed maxillary expansion through an assessment of dento-skeletal effects on posteroanterior cephalometry"	Comparison of dentoskeletal effects between RME and SME	RME : 21 patients 8.8 ±1.37 yo MME : 21 patients 8.9±2.34 yo	Cephalometric study Pre-treatment, during and post-treatment Unspecified	NSD between RME and MME for maxillary expansion and opening of the palatal suture RME: 6,07mm MME: 6,57mm
Melgaço M.A. **2014** (13)	Randomized clinical trial	"Rapid maxillary expansion effects: An alternative assessment	Developing a method to evaluate palatal	Haas: 17 patients	CBCT	NSD between Haas and Hyrax expanders

		method by means of cone-beam tomography"	and lingual transverse changes in patients with RME	Hyrax:14 patients	Maxilla: Palatal cusp tip of PM1 Mesopalatal cusp tip of M1 Mandibula: Center of four central incisors Cusp tip of Canine Lingual cusp tip of PM Mesolingual cusp tip of M1	Maxilla: IM: 5,5±1,46 IPM1: 5,57±2,4 Mandible: IM: 1,74±1,29 IPM1: 1,7±2,69
Grassia V. **2015** (11)	Retrospective study	« Comparison between rapid and mixed maxillary expansion through an assessment of arch changes on dental casts »	Comparison of model cast's patients treated with RME or SME	RME : 21 patients 8.8 ±1.37 yo MME : 21 patients 8.9±2.34 yo	Dental casts Arch circumference Intercanine width - intercentroid Intermolar witdh - intercentroid Interpremolars widths - intercentroid	RME/MME: Better transverse superior arch dimension RME- Maxilla: IM: 8,8 IPM2: 7,28 IMP1: 6,82 IC: 4,3 RME- Mandible: IM:1,5 IMP2:1,17

						IMP1:0,8 IC:0,85
Mutinelli S. **2015** (15)	Retrospective study	« Anchorage onto deciduous teeth: effectiveness of early rapid maxillary expansion in increasing dental arch dimension and improving anterior crowding »	Effectiveness of early RME with deciduous teeth anchorage	20 patients 7yo 1month	<u>Dental casts</u> Arch circumference Intercanine width – inter cusp tip Intermolar width – inter mesopalatal cusp tip	Anchorage onto deciduous teeth allows better arch expansion than Anchorage onto permanent teeth <u>Maxilla:</u> IC:6,4 IM:4,8
Mohan C.N. **2016** (21)	Prospective study	"Long-term stability of rapid palatal expansion in the mixed dentition vs the permanent dentition "	Comparison of stability treatment in mixed or permanent dentition	74 minor patients at the beginning of the treatment	<u>Dental casts</u> Intercentroid points of each tooth Pre, post and long terms dental casts analysis	NSD between mixed or permanent dentition <u>Maxillary Width:</u> 5,80±1,1
Pereira J. **2017** (9)	Randomized clinical trial	"Evaluation of the rapid and slow maxillary expansion using cone-beam computed tomography: a randomized clinical trial"	Evaluate skeletal and dental alterations after RME or SME with Haas expander	<u>RME :</u> 21 patients 8.43 yo <u>SME :</u> 16 patients 8.70 yo	Cephalometric study Base of maxilla Alveolar crest Intermolar width – inter mesopalatal cusp tip	RME: more skeletal changes and more molar inclination SME/RME: NSD for transverse expansion Maxillary width for RME: 62,5% Maxillary width for SME: 61,2%
Pham V. **2017** (18)	Randomized clinical trial	"Alveolar bone level changes in maxillary expansion treatments	Determinate the alveolar bone	<u>Bone anchored expander:</u>	CBCT	NSD between control group and treated patients

		assessed through CBCT"	changes with CBCT	21 patients QDH: 20 patients Control: 21 patients	AZIVIO software	
Lanteri V. **2016** (19)	Retrospective study	« Comparison between RME, SME and Leaf Expander in growing patients: a retrospective postero-anterior cephalometric study »	Comparison between RME, SME and Leaf Expander in growing patients	RME : 10 patients 8.9 yo SME : 10 patients 12.2 yo LE: 10 patients 7.9 yo	Cephalometric study Upper molar: the most prominent lateral point on the buccal surface of the upper first molar. Lower molar: the most prominent lateral point on the buccal surface of the lower first molar.	RME: Maxilla: IM:5,4±3,3 Total : 4,2±3,6 Mandible: 3,3±4,4 SME: Maxilla: IM:5,5±3,5 Total: 2,8±2,8 Mandible: 2,0±1,7 Leaf expander:Maxilla IM:3,8±2,1 Total:3,6±2,2 Mandible: 1,4±1,6
Lanteri V. **2018** (16)	Pilot study	« Maxillary tridimensional changes after slow expansion	Maxillary tridimensional changes after	10 patients 7.5±0.7 yo	Digital dental casts	Posterior crossbite treated in 4 months with Leaf expander

		with leaf expander in a sample of growing patients: a pilot study »	slow expansion with leaf expander in a sample of growing patients		Upper molar: the most prominent lateral point on the buccal surface of the upper first molar. Lower molar: the most prominent lateral point on the buccal surface of the lower first molar.	Maxilla: IC: 6,07±0,83 IM: 3,60±0,72 IM deciduals: 6,17±0,78 Mandible: IC:0,77±0,65 IM: -0,02±1,07
Ribeiro G.L.U. **2020** (17)	Randomized clinical trial	« A preliminary 3-D comparison of rapid and slow maxillary expansion in children »	3D comparison between RME and SME	RME 16 patients SME 13 patients ±8.18 yo	CBCT IC : inter cusp tip IM : inter mesopalatal cusp	RME: IM:6,64±1,95 IC: 3,57±2,04 SME: IM: 4,10±1,66 IC: 2,96± 1,35

3.6 Statistical analysis of the data

All articles' data about amount of expansion (in mm) with either RME or SME therapeutic approaches were collected in **Annexe 1** and analysed in **Table 6**. Not all teeth amount of expansion were reported in the articles, as the majority focused on the intercanine and intermolar widths. The weighted average of all collected data was calculated as a reference for the expansion movement. RME has shown a mean maxillary expansion of 5,7mm and mandibular of 2,1mm whereas SME has shown a mean maxillary expansion of 4,9mm and mandibular of 1,3mm.

Table 6 - Comparison of collected data from selected articles about RME and SME amount of expansion movement

RME		SME	
Maxillary	Mandibular	Maxillary	Mandibular
5,7 mm	2,1 mm	4,9 mm	1,3 mm

Results (in mm) of our clinical study were compared to the one obtained from the selected articles of this integrative systematic review (**Table 7**). Invisalign First® system has shown a mean maxillar expansion of 3,5mm and mandibular of 2,1mm. On the other hand, RME and SME has shown respectively 5,7mm and 4,9mm of mean maxillary expansion and 2,1mm and 1,3mm of mean mandibular expansion.

Table 7 - Overview of the different amount of expansion with Invisalign First®, RME and SME

	MAXILLA	MANDIBULA
Invisalign First®	3,5mm	2,1mm
RME	5,7mm	2,1mm
SME	4,9 mm	1,3mm

4 DISCUSSION

This clinical study compared to an integrative systematic review aims to discuss the effectiveness of rapid and slow maxillary expansion treatments using fixed or removable expanders in the mixed dentition. Nine randomized control trials that met the inclusion criteria were included. For better understanding and interpretation of the results, this analysis should compare the therapeutical expansion approaches and appliances available.

4.1 RME compared to SME

In this integrative systematic review, two therapeutical approaches were considered: RME and SME. In the case of RME, the amount of expansion usually fluctuates in growing children from about 0.2 mm to 0.5 mm per day over a period of 1 to 4 weeks. Whereas SME is characterized by 0.25mm of expansion every other day (7-11).

Rapid maxillary expansion (RME) is indicated whenever an orthopaedic effect is desired for transverse spatial repositioning of the maxilla. Therefore, it is intended for patients with unilateral, bilateral or total dentoskeletal crossbites, in the deciduous, mixed and permanent dentition phases. Furthermore, palatine disjunction may be indicated in cases of posterior dental crossbite of great magnitude (12). On another side, slow maxillary expansion (SME) expanders are indicated for the correction of dentoalveolar crossbites involving groups of dental elements, whether unilateral or bilateral (12). The slow maxillary expansion (SME) appliances are the same as the one used for the rapid maxillary expansion (RME). They can be tooth anchored onto the deciduous or permanent dentition as the difference result in the activation screw expander protocol.

The main difference between Haas and Hyrax-type expanders is the acrylic plate next to the palate in the Haas-type appliance. According to Haas, this acrylic plate aims to distribute the forces applied to the maxilla and thus lead to more orthopaedic modifications and a greater expansion of the skeleton. The study by Melgaço C.A. et al (13) supports Haas' theory, thus more skeletal effects were identified, when compared to the study by Weissheimer A. et

al (14), where the Hyrax-type expander produced greater skeletal expansion. However, these differences represent less than 0.5 mm on each side and are clinically insignificant.

The effects of expansion appliances anchored onto deciduous teeth for the correction of transverse discrepancy of the maxilla in growing patients showed a significant change of the dental arch (15,16). Furthermore, choosing to anchor the appliances to the temporary teeth may avoid the side effects of periodontal disturbances, root resorption and white spot lesions (16).

RME and SME produced less expansion than the 8 mm total screw activation. 83% with RME and 51% with SME were achieved for screw opening at the intermolar width level in the study by Ribeiro G. et al (17). The study by Weissheimer A. et al (14) was the only one in this integrative systematic review that reported expansion values of 7.7mm and 7.9 mm over the 8mm screw activation at the molar level immediately after RME with Haas and Hyrax. Martina R. et al (7) concluded that the amount of palatal expansion did not differ significantly between the two groups and was similar to the findings in the articles by Melgaco CA. et al (13), Weissheimer A. et al (14), Pham V. et al (18) and Lanteri V. et al (19). Thus, according to Martina R. et al (7) and Wong CA. et al (20), SME may be preferable to RME as it reduces the discomfort and pain that patients may experience during treatment (13).

All articles' data about amount of expansion with either RME or SME therapeutic approaches were collected in **Annexe 1** and analysed in **Table 6**. Not all teeth amount of expansion were reported in the articles, as the majority focused on the intercanine and intermolar widths. Some of the articles, only referred the maxillary width (7,8,21). The weighted average of all collected data was calculated as a reference for the expansion movement. The findings of the studies would suggest that RME and SME can be considered two effective therapeutic approaches options to improve the transverse arch dimension and obtain space in the dental arches in growing patients, as the difference is less than 1mm (0,4mm) on each side of the maxillary dental arch. SME and RME have a similar effect on the dentofacial structures in the transverse, vertical and sagittal planes in children with mixed dentition (11,22) and produce amount of expansion that are non-significatively different as reported in the **Table 6.**

4.2 Fixed expanders compared to removable expanders

In this integrative systematic review, we included three studies (23-25) that compared fixed appliances to removable appliances. The studies enrolled children aged 8 to 10 years in early mixed dentition. The studies suggest that Quadri-helix or Hyrax fixed appliances may be 20% more likely to correct crossbites than removable expansion appliances, however the results may not be the same in the permanent dentition (23,25).

Regarding molar expansion, the study by Petren S. et al (23) suggests that Quadri-helix can achieve 1.15 mm more expansion when compared to removable expanders. Similar results were found in the study by Weyrich C. et al (24), for which a significant expansion of 5.74 mm ($p < 0.001$) of the dental arch in the region of the first permanent molars was detected with fixed appliances, compared to an average expansion of 4.62 mm achieved by removable appliances. Descriptive statistics were reported in **Annexe 1**.

The studies by Petren S. et al (23), Weyrich C. et al (24) and Godoy F. et al (25) concluded that the clinical evidence is not sufficient to support that crossbite correction is more successful when using a fixed Quadri-helix appliance than when using a removable expansion appliance.

Finally, Godoy F. et al (25) concluded that fixed expanders are the most cost-effective choice for maxillary expansion treatment, although the main disadvantage is their frequent fracture. Consequently, the decision to use one or another type of expansion appliance can be based on each patient's situation regarding compliance with the treatment plan, presence of anchorage teeth and oral hygiene, without the risk of prejudicing the outcome (24).

4.3 Invisalign First® compared to conventional expanders

Tooth crowding is a major cause why people seek orthodontic treatment. The expansion of a compressed dental arch as a treatment method to correct crowding can increase the length of the arch, which provides more space for tooth alignment. It can also increase the transverse dimension of the smile or correct posterior dentoalveolar transverse crossbites.

Understanding the efficiency and effects of arch expansion treatment using Invisalign First® aligners on skeletal and dental structures is crucial for orthodontists. In the current study, the amount of expansion prescribed for each patient was individually based on measurements of the dentition (6,26-28).

The results of our clinical study showed that Invisalign First® aligners can achieve arch expansion, as the expansion efficiencies were 63,5%, at the canine cusps tip, 62,1% at the first premolar palatal cusps tip, 63,6% at the second premolar palatal cusps tip and 61,1% at the mesolingual cusps tip of the first molar, of the predicted amount of expansion by the Clincheck® software. The total effectiveness of maxillary expansion was 62,6% with the Invisalign First® clear aligners. We noticed a slight decrease in effectiveness from anterior maxillary teeth (canines 63,5%) compared to posterior teeth (first molars 61,1%). This observation was consistent throughout the analysis of the 24 selected cases for this investigation. This result might be due to differences in anatomical root of canines and molars, higher cortical bone thickness of the canine region, and higher resistance of the cheek's posterior region soft tissue (29,30). An additional hypothesis is that the directed force delivered by the Invisalign First® decreases because of the aligners' material resistance (29). In turn, the total effectiveness of mandibular expansion was 58,7% with a predicted mean expansion of 3.5 mm by the Clincheck® software and a clinical achieved expansion of 2,1mm. On the other hand, we observed an increase in the effectiveness from the anterior mandibular teeth (canines 53,2%), compared to posterior teeth (first molars 66,8%). Those results could be explained by the transition from mixed to permanent dentition, the differences between deciduous and permanent teeth widths and the fact that the material resistance is reduced because the upper arch is widened at the same time and has an impact on the mandibular expansion (31).

A slight difference between SME and Invisalign First® amount of expansion was found, as the average maxillary clinical expansion was 3,5mm with the clear aligners and 4,9mm with the conventional SME appliances, meaning less than 1,0mm difference on each side of the maxillary arch. By contrast, RME expanders showed a greater amount of clinical expansion (5,7mm) compared to the Invisalign First® system (3,5mm) (**Table 7**). In our clinical study, a 62,6% efficiency for maxillary expansion was determined. With the RME therapeutical approach, 83% were achieved for screw opening at the intermolar width level, and 51% with

SME, in the study by Ribeiro G. et al (17). Pereira J. et al (9) reported an efficiency of 62,5% for the RME approach and 61,2% for the SME approach, results that are similar as the one found in our clinical study. Regarding the objective to evaluate the effectiveness of the Invisalign First® system for arch expansion, the data obtained indicate that Invisalign® clear aligners are an effective tool to achieve transverse expansion, since the results obtained showed an increase in all tooth widths to a greater or lesser degree due to growth potential development and the influence of bone metabolism on tooth movement during puberty (31). The orthodontist must consider the patient compliance and the mean time of use of the aligners during the days, as these criteria have an influence on the efficiency of the Invisalign First® aligners (6).

Nowadays, children and adolescents undergoing orthodontic treatment prefer appliances that ensure better aesthetic. So, it is fair to say that this system has been a breakthrough in the world of orthodontic treatments, as it is a removable appliance made of a clear thermoplastic material. Invisalign First® can provide the aesthetic that a conventional fixed appliances cannot and therefore attracts more and more patients.

Since Invisalign First® aligners are removable, patient motivation is key to achieve the intended outcome. Noncompliance is one of the main disadvantages of removable appliances and can cause treatment hardships such as more time-consuming process until reaching the intended objectives, or even relapse of the initial malocclusion (6,28). At the same time, fixed appliances have their disadvantages such as less comfort for the patient with larger appliances in mouth, greater pain during activation protocol and frequent fracture (7,20).

5 LIMITATIONS

- The articles were selected in the time range from 2010 to 2021 to focus our goal on identifying more recent evidence on the effectiveness of maxillary expansion treatments. As Invisalign First® is a new approach to expansion treatment, introduced in 2018, we needed recent information about conventional expanders used in mixed dentition to be compared at.

- As far as the standardization criteria used in the recruitment and selection of candidates are concerned, they should be objective, reproducible and described in future studies in order to eliminate the variability of the examination results.

- As the standardization criteria used in the measurements of the different widths are concerned, they should be always specified and reproductible in future studies in order to eliminate the variability of the error examinator and the selection of the reference points.

- However, further investigations are needed regarding the expansion movement with the Invisalign First® system in order to better understand the behaviour of different groups of teeth when submitted to this movement in mixed dentition.

6 CONCLUSION

The outcomes of our clinical study compared to an integrative systematic review about Invisalign First® system and conventional expansion appliances, led to the conclusion that:

- There is no significative difference between RME or SME amount of expansion. They can be considered two effective therapeutical approaches to improve the transverse arch dimension;
- The fixed appliances seem to have more probability to correct posterior crossbite than the removable one;
- Invisalign First® system has similar outcomes with conventional removable appliances regarding the efficiency of maxillary expansion, even if achieving similar results to those of more conventional fixed appliances may be difficult;
- The Invisalign First® system can provide an excellent aesthetic during treatment, ease of use, comfort of wear and superior oral hygiene than fixed appliances;
- An overcorrection seems to be necessary for both of fixed and removable appliances to provide clinically satisfying results.

The Invisalign First® system is at the technological forefront when it comes to removable orthodontic treatment. It is essential that a greater number of studies be carried out about this topic, which would contribute to a more accurate and well-founded response to the structural question of this clinical study compared to an integrative systematic review.

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8 ANNEXES

Annexe 1 - descriptive collected data from selected articles about RME and SME expansion

		RME										SME/MME									
Author and year of publication	Appliances	MAXILLA					MANDIBULA					MAXILLA					MANDIBULA				
		IC width	IPM1 width	IPM2 width	IM1 width	Max width	IC width	IPM1 width	IPM2 width	IM1 width	Mand width	IC width	IPM1 width	IPM2 width	IM1 width	Max width	IC width	IPM1 width	IPM2 width	IM1 width	Mand width
Ramoglu S.I. 2010 (25)	type tooth- and tissue-borne modified bonded RME	4,77	-	-	5,11	-	0,38	-	-	0,12	-	5,13	-	-	5,71	-	0,40	-	-	-0,01	-
Huynh T. 2010 (11)	Haas	-	-	-	-	5,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hyrax					5,1															
	QDH					4,7															
Weyrich C. 2010 (27)	EP	3,59	-	-	4,62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RME	2,81			6,38																
	Mod. RME	5,11			5,74																
Godoy F. 2011 (28)	QDH	3,48	-	-	5,70	-	-0,21	-	-	0,46	-	-	-	-	-	-	-	-	-	-	-
	EP	-	-	-	-	-	-	-	-	-	-	1,80	-	-	4,46	-	0,28	-	-	-0,12	-
Weisshimer A. 2011 (17)	Haas	-	-	-	5,8	7,70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hyrax	-	-	-	7,35	7,90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wong C.A. 2011 (23)	Haas	-	-	-	-	-	-	-	-	-	-	4,56	-	-	4,32	-	-0,19	-	-	0,27	-
	Hyrax																				
	QDH																				
Petren S. 2011 (26)	QDH											2,7			4,1		-0,5			-0,1	
	EP											2,6			3,8		0,5			1,2	
Martina R. 2012 (10)	Two banded palatal expanders	-	-	-	-	5,7	-	-	-	-	-	-	-	-	-	6,3	-	-	-	-	-
Çorekçi B. 2013 (30)	Hyrax	5,13	-	-	5,43	-	0,52	-	-	0,32	-	-	-	-	-	-	-	-	-	-	-
	Ragno	5,38			1,44		0,84			0,95											
Perillo L. 2014 (13)	Hyrax	-	-	-	9,17	6,07	-	-	-	2,67	-	-	-	-	10,21	6,57	-	-	-	3,54	-
Melgaço M.A. 2014 (16)	Haas	-	5,57	-	5,5	-	-	1,70	-	1,74	-	-	-	-	-	-	-	-	-	-	-
	Hyrax																				
Grassia V. 2015 (14)	Hyrax	4,3	6,82	7,28	8,8	-	0,85	0,8	1,17	1,5	-	3,70	7,33	6,9	8,7	-	1,13	1,91	2,36	2,09	-
Mutinelli S. 2015 (18)	Haas	6,4	-	-	4,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mohan C.N. 2016 (24)	Haas	-	-	-	-	6,17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pereira J. 2017 (12)	Haas	-	-	-	-	5,0	-	-	-	-	-	-	-	-	-	4,9	-	-	-	-	-
Lanteri V. 2018 (22)	Haas	-	-	-	5,4	4,2	-	-	-	-	3,3	-	-	-	5,5	2,8	-	-	-	-	2,0
	EP											-	-	-	3,8	3,6	-	-	-	-	1,4
	Leaf Expander																				
Lanteri V. 2018 (19)	Leaf Expander	-	-	-	-	-	-	-	-	-	-	6,07	-	-	3,6	-	0,77	-	-	-0,02	-
Ribeiro G.L.U. 2019 (20)	Haas	3,57	-	-	6,64	-	-	-	-	-	-	2,96	-	-	4,10	-	-	-	-	-	-
MEAN EXPANSION FOR TOOTH TYPE		4,5	6,2	7,3	5,9	5,8	0,5	1,3	1,2	1,1	3,3	3,7	7,3	6,9	5,3	4,8	0,3	1,9	2,4	0,9	1,7
WEIGHTED AVERAGE			5,5			5,8		0,9			3,3		4,9			4,8		0,8			1,7
Total Mean			5,7					2,1					4,9					1,3			