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Review Article

Effectiveness of maxillary arch expansion with clear aligners in mixed dentition: A research synthesis and meta-analysis

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Abstract

Objective: This systematic review aimed to evaluate the scientific evidence on effectiveness of maxillary arch expansion in the mixed dentition with clear aligners.

Materials and Methods: Eight electronic databases were searched: PubMed, Web of Science, Embase, Cochrane Library, Science direct, Google scholar, Scopus, and LILACS until June 2023. Randomized clinical trials, Prospective and retrospective studies on subjects requiring dentoalveolar expansion in mixed dentition phase, treated with clear aligners were included. After inclusion of studies, eligibility screening, data extraction and risk of bias assessment were performed and exploratory meta-analyses of the mean differences (MDs) with their 95% confidence intervals (CIs) was conducted.

Results: A total of seven articles were included: Four retrospective, two prospective and one randomized controlled trial. Four studies presented low risk of bias, two studies showed moderate risk of bias and the randomized controlled trial had some concerns. Results revealed that the maximum amount of arch expansion with clear aligners was observed at first deciduous intermolar region with mean expansion of 3.52 mm and least amount of expansion was observed at the deciduous inter-canine region with a mean expansion of 2.63mm.

Conclusions and Implications: The clear aligners were able to produce considerable arch expansion of 3-4 mm in the mixed dentition stage.

Keywords: Arch expansion, Clear aligners, Mixed dentition, Transverse discrepancy, Dentoalveolar expansion

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1. Introduction

Orthodontic treatment during mixed dentition is crucial for addressing malocclusions and skeletal discrepancies in developing dentition. The correction of transverse discrepancies at this stage holds significant importance as it profoundly influences overall jaw growth in all three planes of space.[1,2] Arch expansion, a pivotal component of orthodontic intervention, plays a crucial role in achieving proper occlusion and facial harmony. Traditional orthodontic approaches, such as fixed appliances and palatal expanders, have been employed to address arch expansion,[3,4] However, recent advancements in orthodontic technology have introduced clear aligners as an alternative modality for managing malocclusions in mixed dentition,[5] The mixed dentition period is characterized by the presence of both primary and permanent teeth, presenting a unique set of challenges and opportunities for orthodontic intervention. Arch expansion during this phase is essential for accommodating erupting permanent teeth, correcting crowding issues, enabling sagittal growth and establishing an optimal foundation for subsequent orthodontic treatment phases[6,7] Clear aligners have gained popularity for their esthetic appeal, comfort, and patient compliance.

The arch expansion achieved with clear aligners is primarily dentoalveolar in nature, accomplished through the buccal tipping of the posterior teeth,[8] The enhanced effectiveness of expansion with clear aligners is reportedly observed when correcting arches that are not skeletally constricted, typically falling within the range of 0.1 to 5.0 mm. With the introduction of newer aligner materials and smart attachments, the predictability of expansion with clear aligners in adults has been reported to range between 70%

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and 80%. While the effectiveness of clear aligners in managing transverse discrepancies in adults is well-documented, their specific impact on arch expansion during mixed dentition remains an area of ongoing investigation.

This research seeks to comprehensively evaluate and elucidate the effectiveness of clear aligners in achieving successful arch expansion in mixed dentition patients. This knowledge may guide clinical decision-making, enhance treatment planning strategies.

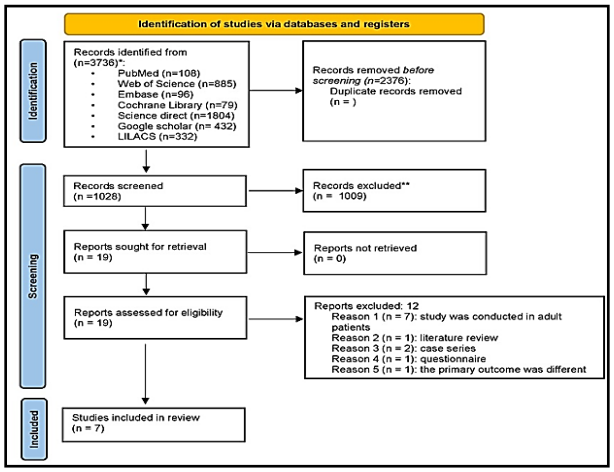

Figure 1: PRISMA2020 Flow diagram for new systematic review which included searches of databases and registers only

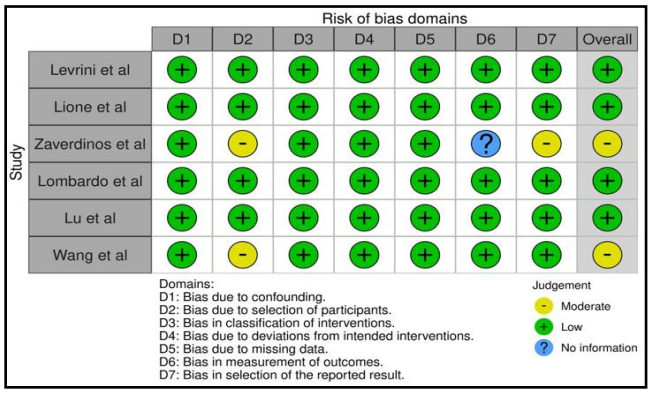

Figure 2: Risk of bias of the included observational studies.

Table 1 in PICOS format.

2.2. Search strategy and data collection

Data search was carried out in seven electronic databases: PubMed, Web of Science, Embase, Cochrane Library, Science direct, Google scholar, LILACS and grey literature. Articles published only in English were included for the review. The search enclosed results up until June 2023. An update/re run was performed in August 2023. A detailed list of the search strategy is enumerated in **Table 2**. Two authors (DS, GV) performed the search and the results were imported

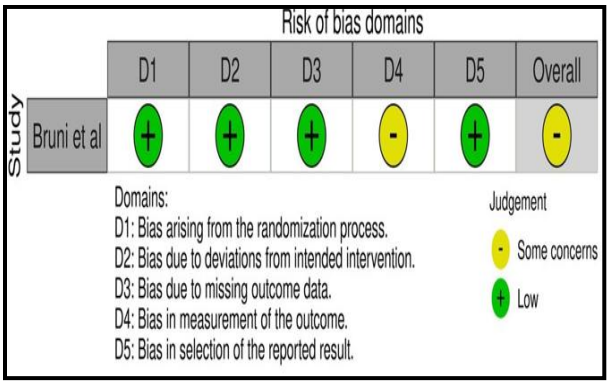

Figure 3: Risk of bias of the included randomized clinical trial.

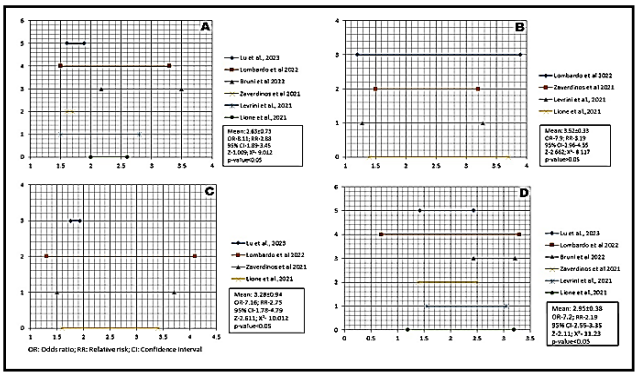

Figure 4: Forest plot depicting transverse changes A,at deciduous canine among various studies; B,at first deciduous molar among various studies; C, at second deciduous molar among various studies; D,at first permanent molar among various studies.

2. Materials and Methods

This systematic review was registered at the International Prospective Register of Systematic Reviews, PROSPERO (CRD42023437370) and adhered to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

2.1. Eligibility criteria

The eligibility criteria are presented in

in a reference management software (Zotero version 6.0.26) where the duplicates were removed. Manual screening of the title and abstract of the remaining articles were performed by two authors. A total of 19 articles were retrieved and subjected to full text evaluation. Selection was based on the eligibility criteria as mentioned before. The third author (TT) was sought for final decision before completion of search strategy. Any disagreements between the authors were sorted by consulting the third author. The process of screening, evaluation, inclusion and exclusion of articles is summarized in the PRISMA flowchart, **Figure 1**. A total of 7 articles were included for final review.

All the included studies were evaluated and relevant data was manually extracted by two authors(TT, GV) and tabulated in an excel sheet. The table included details on the authorship, year of the study, study design, objective of the study, inclusion criteria (sample size, age range, clinical characteristics (amount of transverse discrepancy), measurement method, results (mean values of the amount of expansion) and conclusion.

2.3. Quality assessment of individual studies

Methodological quality of the individual studies was assessed by different risk of bias tools based on the study design. For Randomized controlled trials, Cochrane risk of bias tool (RoB 2.0) and for observational studies (prospective or retrospective), ROBINS-I tool[10] were used. For RoB the following domains were considered: Bias arising from the randomization process; Bias due to deviations from intended intervention; Bias due to missing outcome data; Bias in measurement of the outcome; Bias in selection of the reported result. After consensus between the first two authors (DS, GV) the study was classified under low, some concerns or high risk of bias. For ROBINS-I tool, seven domains were considered: Bias due to confounding, Bias in selection of participants into the study(or into the analysis), Bias in classification of interventions, Bias due to deviation from intended intervention, Bias due to missing data, Bias in measurement of the outcome and Bias in selection of the reported result. After analyzing the articles according to the above said domains, judgements were made as follows: low, moderate, serious and critical risk of bias. The third author (TT) was consulted in case of any conflict of judgement and the final decision was made.

2.4. Summary of measurements and synthesis of results

A qualitative synthesis of the studies was reported initially. Further, the homogeneity of the methodology and outcome measures were assessed. Based on the results, a quantitative evaluation (meta-analysis) was planned using IBM SPSS 20.0 version. The pooled means with 95% confidence interval was calculated for the following outcomes/parameters: age, treatment duration, inter-canine width, first deciduous intermolar width, second deciduous intermolar width, first permanent molar width. The heterogeneity among the studies was assessed using a chi square test and was quantified by the I^2 statistics.

3. Results

3.1. Study selection

The electronic search yielded 3736 articles from seven electronic databases. Removal of duplicates (n= 2376) was performed in Zotero software, following which a total of 1028 articles remained. Title and abstract screening were performed for the 1028 articles. In case of uncertainty after reading the title and abstract, the article was evaluated by full text reading. A total of 19 articles were sought for retrieval. These articles were assessed for eligibility based on the inclusion and exclusion criteria. Twelve articles were excluded after full text evaluation for various reasons. A total of seven studies were finally included. The process of identification, screening and inclusion is explained in PRISMA flow diagram **(Figure 1)**

3.2. Study characteristics

The study characteristics are presented in **Table 3** and **Table 4** Out of the 7 studies, two studies were prospective,[11,12] one was a randomized controlled trial[13] and four studies were retrospective[14-17] The study design by Bruni et al[13] was mentioned as randomized controlled trial, however, the study did not comprise a control group, rather had an active comparator group in which another type of expansion appliance was given. Hence, after discussion and consensus among all the authors, the study was considered as a randomized clinical trial and not as a randomized controlled trial.

3.3. Characteristics of the study participants

All the studies were conducted in both males and females. The age of the participants ranged between 6 to 12 years, except for one study in which age range was not mentioned and patients from CVMI 1 to 3 were included.[12] All the seven studies included patients in mixed dentition stage and had fully erupted permanent maxillary first molars. Lione et al and Cretella Lombardo et al included patients with a posterior transverse discrepancy between maxillary and mandibular arches up to 6mm.[11,15] Two studies[12,13] had an inclusion criteria of posterior transverse discrepancy between maxillary and mandibular arches less than or equal to 5mm. Studies by Wang et al and Zaverdinos et al did not mention about the transverse discrepancy.[16,17]

3.4. Characteristics of the intervention

All the patients were treated with Invisalign First system and the software planning was done by ClinCheck. Sequential staging pattern of expansion was performed as planned by the software in all the studies. The protocol of “molars move first” was followed by five studies in which details about the sequencing of expansion were mentioned[11,13,15,17] first expansion on the permanent maxillary first molars followed by deciduous canines and molars. The total number of aligners used were mentioned by Levrini, Lione and Wang et al,[11,14,17] whereas frequency of change was mentioned by all the studies except Bruni and Zaverdinos et al.[13,16] Total expansion duration ranged from approximately 6 months to 1 year. Amount of expansion per stage of aligners was mentioned by three studies, 0.15mm of expansion by Lione et al and Cretella Lombardo et al, 0.25mm of expansion by Wang et al.[11,15,17]

Table 1: Eligibility criteria

Category	Inclusion criteria	Exclusion criteria
Population	Mixed dentition with the presence of maxillary 1st permanent molars, growing patients with mild to moderate transverse discrepancy requiring expansion.	Studies conducted on adults, patients requiring extraction, subjects treated with fixed or other expansion appliances. Growing patients with systemic diseases and /or craniofacial pathologies. Literature reviews, case series, author opinion, letter to editor.
Intervention	Maxillary arch Expansion with clear aligner therapy.	
Comparison	Pre-treatment and post-treatment maxillary arch width changes.	
Outcome	Transverse arch width changes in the maxilla.	
Study design	Randomized Controlled Trials/clinical trials, prospective and retrospective studies.	

Table 2: Search strategy

Database	Search strategy/ keywords	Results
PubMed	((mixed dentition[Title/Abstract] OR growing[Title/Abstract]) AND (invisalign first[Title/Abstract] OR clear aligner[Title/Abstract] OR aligner[Title/Abstract])) AND (maxilla*[Title/Abstract] OR expan*[Title/Abstract] OR dimension*[Title/Abstract] OR palat*[Title/Abstract] OR upper[Title/Abstract] OR development*[Title/Abstract] OR molar[Title/Abstract] OR canine[Title/Abstract] OR dent*[Title/Abstract]))	108
Web of Science, Embase, Cochrane Library, Science Direct, Google scholar and LILACS Grey literature	“mixed dentition” OR “growing” AND “maxillary arch expansion” OR “upper arch width” AND “invisalign first” OR “clear aligner”	Web of Science (n=885); Embase (n=96); Cochrane Library (n=79); Science Direct (n=1804); Google scholar (n= 432); LILACS (n=332) Grey literature (n=0)

Table 3: Characteristics and synthesis of included studies

S. No.	Study & year	Study Design	Objective	Number of subjects and gender distribution	Age range (Year) Mean (SD)	Treatment modality	No. of Aligners (frequency of aligner change)	Average Treatment duration
1.	Lione et al., 2021(1)	Prospective study	To evaluate the transverse maxillary arch development with the Invisalign First System® in growing subjects.	23 (9 females, 14 males)	9.4 (1.2) years	The Invisalign First System®	37 (change every 7 days)	8.1 months
2.	Levrini et al., 2021(2)	Retrospective study	To evaluate dentoalveolar changes in patients treated with Invisalign® First clear aligners in the mixed dentition focusing on maxillary arch width, arch perimeter, arch depth, molar inclination and alveolar expansion.	20 (12 females and 8 males)	8.9 (NM) years	The Invisalign First System®	33 (change every 14 days)	8 months
3.	Zaverdinos et al., 2021 (6)	Retrospective study	to investigate the magnitude of expansion of the Invisalign First clear aligner appliance compared to a Schwartz removable expander in patients with mixed dentition.	16 subjects (Gender distribution not mentioned)	8.8 years (NM)	Invisalign® First System	NM	7.2 months
4.	Lombardo et al., 2022(4)	Retrospective study	to compare the effects of two different expansion protocols in terms of bidimensional (2D) transversal linear and angular measurements, and threedimensional (3D) analysis of palatal surface area on digital casts in a group of patients with early mixed dentition.	15 (8 females, 7 males)	8.4 (1.1) years	Invisalign® First System	NM (change every 7 days)	8 months
5.	Bruni et al., 2022(5)	Randomized clinical trial	to evaluate the effects on the palatal volume and surface area measurements, as well as on the inter-dental linear measurements, produced by	39 patients (Gender distribution not mentioned)	8.48 (1.42) years	Invisalign® First System	NM	8 months

			CAT compared with RPE in mixed dentition patients.					
6.	Wang et al., 2023 (7)	Retrospective study	To compare palatal dimensions and molar inclinations after Invisalign First System (IFS) to those in patients treated with slow maxillary expansion (SME) and normal controls.	51 subjects (Gender distribution not mentioned)	8.45 (0.67) years	Invisalign® First System	28 (change every 7 days)	14 months
7.	Lu et al., 2023(3)	Prospective cohort study	To compare the dento-skeletal effects of using Invisalign First System with Hass excluding growth factors	51 subjects (Gender distribution not mentioned)	6-10 years	The Invisalign First System®	NM (change every 7 days)	6 months

Table 4: Method of assessment and outcome of included studies

S. No.	Study & Year	Method of assessment	Software used for assessment	Parameters assessed	Outcome- pretreatment – posttreatment (Mean±SD)	Conclusion
1.	Lione et al., 2021(1)	Pre-treatment and post-treatment digital models (.stl files)	Viewbox 4 software (dHAL software, Ki-fissia, Greece)	Intercanine width (III–III)	2.6 ± 2.0 mm	The greatest increase of maxillary width was detected at the level of upper first deciduous molars, followed by expansion at the level of the second deciduous molars and by expansion at the level of the deciduous canines. The upper first molars showed the greater expansion in the intermolar mesial width due to the rotation that occurred during the expansion around the palatal root of the tooth acting as a hinge.
				First interdeciduous molar width (IV–IV)	3.7±1.4 mm	
				Second interdeciduous molar width (V–V)	3.4 ±1.6 mm	
				First permanent intermolar width (6-6)	3.2 ±1.2 mm	
				First intermolar distal width (6–6 distal cusps)	1.7 ±1.2 mm	
				First intermolar transpalatal width (6–6 transpalatal)	1.2±1.2 mm	
2.	Levrini et al., 2021(2)	Pre-treatment and post-treatment digital Models (.stl files)	Three-dimensional digital parametric inspection software (GOM Inspect	Intercanine width (III–III)	2.8±1.51 mm	In case of mild crowding or limited transverse maxillary deficiency, Invisalign® First clear aligners could be a reasonable alternative to traditional slow maxillary expanders.
				First interdeciduous molar width (IV–IV)	3.28±1.28 mm	
				Second interdeciduous molar width (V–V)	3.72±1.47 mm	
				First permanent intermolar width (6-6)	3.05±1.55 mm	

			2019, Braunschweig, Germany)	Canine gingival width	2.01±0.84 mm	
				First deciduous molar gingival width	2.24±0.9 mm	
				Second deciduous molar gingival width	2.59±1.12 mm	
				First permanent molar gingival width	2±1.02 mm	
				Arch depth	-1.24±1.06 mm	
				Arch perimeter	0.85±1.63 mm	
				Molar inclination	-4.62±6.61	
3.	Zaverdinos et al 2021(6)	Pretreatment and first refinement digital models (.stl files)	Align Technology's © Quantify software	Inter-canine width (III-III)	1.7 ± 1.3	There was less expansion achieved in the Invisalign First clear aligner appliance.
				First inter-deciduous molar width (IV- IV)	3.2 ± 1.5	
				Second inter-deciduous molar width (V-V)	3.7 ± 1.5	
				First permanent intermolar width (6-6)	2.5 ± 1.4	
4.	Lombardo et al 2022(4)	Pre-treatment and post-treatment digital models (.stl files)	Viewbox 4 software (dHAL software, Ki	Inter-canine width (III-III)	3.3 ± 1.5	A greater increase of linear measurements in the anterior region of the upper arch in clear aligner group
				First inter-deciduous molar width (IV- IV)	3.9 ± 1.2	
				Second inter-deciduous molar width (V-V)	4.1 ± 1.3	
				First permanent intermolar width (6-6)	3.3 ± 0.7	
				First inter-molar distal width (6–6 distal cusps)	2.1 ± 0.8	
				First inter-molar transpalatal width	2.2 ± 0.6	

				Inter-canine transpalatal width	3.3 ± 0.9	
				First inter-deciduous molar transpalatal width	4.0 ± 0.9	
				Second inter-deciduous molar transpalatal width	4.1 ± 0.7	
5.	Bruni et al 2022(5)	Pre-treatment and post-treatment digital models (.stl files)	reverse modelling software package Geomagic Control X (3D Systems Inc., Rock Hill, SC, USA)	Inter-canine width (III-III)	3.52 ± 2.17	The Clear Aligners demonstrated a reasonable ability to achieve palatal expansion
				First permanent intermolar width (6-6)	3.22 ± 2.43	
				Upper inter-canine width (ICW) – gingival level	3.00 ± 1.81	
				Upper inter-molar width (IMW) – gingival level	1.58 ± 1.53	
				Palatal volume	243.95 ± 473.24	
				Palatal surface	64.51 ± 64.25	
6.	Wang et al 2023(7)	Pretreatment and refinement digital models (.stl files)	Rhinoceros 3D (version 7.0, Robert McNeel & Associates, Seattle, WA).	Intercanine width (ICW)	3.10 ± 1.29	Invisalign first system produced significant increases in intercanine and intermolar width compared to untreated controls.
				Intermolar widths (IMW)	1.95 ± 1.61	
				Palatal surface area (SA)	43.50 ± 39.58	
				Palatal volume (V)	294.85 ± 290.91	
				Molar bucco-lingual inclination (right)	0.24 ± 3.60	
				Molar bucco-lingual inclination (left)	0.08 ± 1.97	
7.	Lu et al., 2023(3)	Pre-treatment	Geomagic Design 2016	Intercanine width (III-III):	1.89±1.56	Invisalign First System is a new method of comfortably and effectively acting on

		and post-treatment(6 months after appliance use) digital Models (.stl files)	software (Geomagic Company, USA)	First interpremolar width (4-4)	2.83±1.90	maxillary expansion, recommended for patients with aesthetic, arch space management needs and mild to moderate narrowing of the maxillary in mixed dentition.
				Second interdeciduous molar width (V-V):	1.93±1.75	
				First permanent intermolar width (6-6)	2.43±1.42	
				Arch depth	-0.46±0.86	
				Arch perimeter	1.69±2.01	
				Intercanine alveolar bone width	1.05±1.14	
				Intermolar alveolar bone width	1.43±0.86	
				Molar inclination	-4.49±6.87	

For specific tooth movements, disto-rotation and 2° extra buccal root torque was programmed in the aligners for each phase of expansion in the studies by Lione et al, Lu et al, Bruni et al, Levrini et al and Cretella Lombardo et al.[11-15] The study by Wang et al did not prescribe any specific derotation or extra buccal root torque.[17]

3.5. Characteristics of the measurements

Various parameters assessed by the studies included linear arch width changes[11-17] palatal volume[13,17] arch depth[12,14] arch perimeter.[12,14] The measurements were performed in digital models (.stl files). Pertaining to the linear arch width measurements, the inter deciduous intercanine width was measured by all the studies from the cusp tip of the canine from one side to the other/opposite side, except for one study[17] which measured the inter deciduous canine width from the palatal gingival embrasure of one side to the other. Similarly, in all the studies, intermolar width was calculated as the distance between the mesiobuccal cusp tips of the maxillary first permanent molar, except by Wang et al[17] which measured the distance between the palatal gingival embrasure corresponding to the mesiobuccal cusp tip of the maxillary first permanent molars. The linear arch width changes were also evaluated in relation to deciduous first molar[11,14,16] deciduous second molar[11,12,14-16] first premolar.[12] Arch perimeter and arch depth were assessed in two studies[12,14] Bruni et al[13]also assessed the changes in the palatal volume.

3.6. Risk of bias assessment

The risk of bias for observational studies was assessed through ROBINS-I tool and the graphical representation is presented in **Figure 2**. Out of the six observational studies, four studies presented low risk of bias, of which two studies, Zaverdinos et al[16] and Wang et al[7] presented a moderate risk of bias. The moderate risk of bias was due to selection of participants as the inclusion criteria did not mention about the indication for correction of the transverse discrepancy. The risk of bias of the randomized clinical trial[13] was assessed by RoB 2.0, which presented some concerns, because of bias in measurement of outcome. **(Figure 3)**

3.7. Results of individual studies and meta-analysis

Owing to the homogeneity in the methodology and outcome of the studies, a meta-analysis could be performed for various parameters. The objective of the meta-analysis was to assess the amount of expansion by clear aligners in mixed dentition with respect to each tooth. The areas of assessment included in the meta-analysis: Intercanine width[11-16] First deciduous intermolar width[11,14,16] second deciduous intermolar width,[11,12,15,16], First permanent molar width[11-16] age and treatment duration. The heterogeneity among the studies was low with an I^2 value less than 50% (p value = 0.183). The pooled mean age was 8.73 (95% CI= 8.33- 9.13), treatment duration 8.47(95% CI = 6.11-10.83). The pooled mean amount of expansion was 2.63(95% CI= 1.86- 3.40) at the intercanine region, 3.52(95% CI= 2.98- 4.05) at first deciduous intermolar region, 3.28(95% CI= 1.77- 4.78) at the second deciduous intermolar region and 2.95(95% CI = 2.54-3.35) at the first permanent molar region **(Figure 4**).

The details of meta-analysis are presented in the supplementary file (**Supplementary Table 1 and 2**

4. Discussion

The present systematic review aimed to assess the effectiveness of clear aligners in maxillary arch expansion in mixed dentition. The synthesis of results from the studies under exploration exhibit that clear aligners can bring about sufficient expansion in mild to moderate cases of transverse discrepancy and crowding.

The evolving practice of clear aligners in mixed dentition is owed to its esthetics, comfort, less pain compared to fixed appliances, decreased number of appointments and a lesser chair side time.[18] Presence of malocclusion in the transverse dimension affects the growth and development in all the three planes of space. One of the fundamentals of early orthodontic treatment in mixed dentition subjects is to correct the transverse discrepancy, enabling sagittal growth, leading to interception of malocclusion, providing a conducive environment for the developing occlusion.[19] The secondary aim of arch development is to relieve crowding in mixed dentition for gaining space. Recently, clear aligners have been used to correct the transverse discrepancy problems, but the question of its effectiveness remains open to debate. This obscurity of a recently used approach necessitates the need for a systematic review and combine the available literature to assess the effectiveness of clear aligners in causing arch expansion in mixed dentition.

An appreciable number of studies were available in the literature and were included in this review. All the studies had a similar objective, to evaluate the transverse changes in the maxillary arch with clear aligners in mixed dentition. The characteristics of the study participants were homogenous, including patients in the age range of 6 to 12 years, mixed dentition along with the presence of maxillary first molars. Indications for the correction of transverse discrepancy was a criteria for eligibility in all the studies except Zaverdinos et al and Wang et al.[16,17]

The clear aligner used by all the studies was the Invisalign First system, alleviating the probability of methodological variations occurring due to the differences in material, thickness, attachments, etc. A method of sequential staging of expansion was adhered by most of the studies. The protocol of “molars move first” tips the molar buccally, rotating around its palatal root, enabling an ideal cusp to fossa relationship and utilizes it as an anchorage unit to move the deciduous canines and mo01lars.[13,17]

The programming of aligners incorporated extra buccal torque of 2 degrees at each step[11-15] to counteract the buccal

tipping effect of expansion, providing a better control on the crown angulation. Levrini et al observed that there was a consistent bodily expansion and a buccal tipping of 4.62 degrees which was comparable to the other expanders.[14] In the study by Wang et al the aligners were designed with Smart force aligner activation and optimized expansion attachments under G8 innovation without the incorporation of extra buccal torque and disto-rotation of molars.[17] They observed that this innovation helped in counteracting the buccal tipping and found no significant changes in the molar inclination before and after treatment. A feature of distorotation of molars was also incorporated in the aligners which rotates the molar distally and changes the arch form from ovoid to parabolic, allowing arch expansion in lateral segments and as an anchorage during buccal displacement of all the teeth.

The magnitude of expansion varied among the studies. A greater amount of expansion was mostly observed in the deciduous first molar region followed by deciduous canine,[11,12,14] In the study by Lu et al more expansion was seen in the first premolar region and least amount of expansion was found in the canines.[12] On the contrary, Cretella Lombardo et al observed more amount of expansion in the canine and the first deciduous molar region.[15] The results of the meta-analysis of the present review revealed that the maximum amount of expansion was observed in the first deciduous molar region (3.52mm; Range= 3.20-3.90) followed by second deciduous molar region (3.28; Range= 1.93-4.10), first permanent molar (2.95mm; Range= 2.43-3.30) and deciduous canine (2.63mm; Range= 1.70-3.52). It is suggested that the aligners are more efficient in causing arch development in the anterior segment while the posterior segments were subjected to more of dental compensations. This was hypothesized to the fact that the reverse V pattern of mid palatal sutural resistance enables more expansion in the anterior region. The findings were similar to the study by Bruni et al which suggested that the aligners are not stiff enough in the distal portion to cause expansion.[13] It is also reported that the mechanical efficiency of aligners to generate a buccally directed force for expansion declines from anterior to posterior.[20] When compensating for the lateral dimension, an invitro study showed that the aligners were more effective in achieving anterior alignment than buccal occlusion.[21]

In comparison to other expansion appliances, Cretella Lombardo et al observed that clear aligners are efficient in causing arch expansion in the anterior region compared to rapid maxillary expansion (RME) devices.[15] The study by Lu et al showed that the arch width changes were more with Hass expander compared to the clear aligners, whereas the buccal tipping of molars were less with the clear aligners.[12] This was attributed to the incorporation of 2-degree buccal torque, making the aligners safe for periodontal tissues. Though overcorrection/better control on crown angulation was predesigned in the aligners, the expansion was purely dentoalveolar.[13]

To address the effect of growth on expansion, one study had a control group which was age and gender matched to the experimental group and no expansion appliance was given. They observed no significant expansion after 6 months in the control group. The maxillary arch width in mixed dentition changes by about 0.3 to 0.5 mm each year in the untreated individuals in the area of the permanent first molars, similar to the findings by Bishara et al, wherein spontaneous transverse growth for a period of 9 months was observed to be 0.5mm for the age group of 8-10 years.[22]

In summary, as per the systematic review conducted, there is considerable evidence suggesting that clear aligners can bring about an expansion of 3-4mm in mixed dentition cases. The expansion is mainly dentoalveolar in nature. It is to be noted that the indications between clear aligners and other expansion appliances like RME and Hass are different, where the former can be given in mild to moderate discrepancy cases and the latter is given where more skeletal expansion is anticipated.]

4.1. Limitations and recommendations

1. Though the methodology was homogenous, all the studies included in this systematic review were mostly retrospective or prospective without a comparison/control group. Well conducted Randomized Clinical Trials with a control group would be necessary to delineate the effects of growth on transverse dimension.

2. Including foreign language literature would further assist in exploring the outcome of maxillary arch expansion with clear aligners in mixed dentition.

5. Conclusion

The literature presents a moderate level of evidence on arch expansion in mixed dentition period with the clear aligners. According to the available evidence, it can be suggested that clear aligners can bring about a dentoalveolar expansion of 3-4 mm. Insufficient evidence regarding the amount of bodily expansion, molar tipping, periodontal condition after expansion necessitates the need for further exploration with clinical trials.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Supplementary Table 1: Mean and standard deviation of technical and clinical parameters among various studies.

	Number of studies	Range	Minimum	Maximum	Mean	Std. Error	Std. Deviation	95% Confidence Interval	
								Lower	Upper
Intercanine width (III–III)	6	1.82	1.70	3.52	2.6350	.29906	.73255	1.8662	3.4038
First interdeciduous molar width (IV–IV)	4	.70	3.20	3.90	3.5200	.16753	.33506	2.9868	4.0532
Second interdeciduous molar width (V–V)	4	2.17	1.93	4.10	3.2825	.47308	.94616	1.7769	4.7881

First permanent intermolar width (6-6)	6	.87	2.43	3.30	2.9500	.15714	.38492	2.5461	3.3539
Age (years)	6	1.00	8.40	9.40	8.7383	.15621	.38264	8.3368	9.1399
Treatment duration (months)	7	8.00	6.00	14.00	8.4714	.96479	2.55259	6.1107	10.8322

Supplementary Table 2: Metanalysis

Pre vs post expansion changes	**Heterogeneity Test**				**Odd ratio OR**	**Relative risk RR**	**95% CI**	**Overall Test**	
	X^2	**df**	**p-value**	**I^2**				Z-test	p-value
III-III	9.0122	5	0.209**	49%	8.11	2.88	1.89-3.45	1.009	0.012*
IV-IV	8.117	3	0.196**	48%	7.90	3.19	2.96-4.55	2.662	0.085
V-V	10.0122	3	0.194**	47%	7.16	2.75	1.78-4.79	2.611	0.036*
VI-VI	11.228	5	0.180**	49%	7.20	2.19	2.55-3.35	2.110	0.042*
*p-value<0.05 is significant; ** p-value>0.05 is insignificant. i^2 <50% in all parameters, showing lack of heterogeneity.									

Publication bias was computed by heterogeneity test. The values of I^2 <50% indicate that there is lack of heterogeneity. ***It means that publication bias is not significant between the studies.*** *We used a Chi square test to assess heterogeneity. Z-test was done to determine the level of significance in relation to transverse changes according to studies and it was observed that a* ***significant relation (p-value<0.05)*** *was obtained between various types of studies.*