Clinical effectiveness of space maintainers and space regainers in the mixed dentition: A systematic review

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Abstract

Background: The aim of this systematic review was to address the clinical effectiveness of space maintainers and space regainers in the prevention and correction of dental arch decrease in the mixed dentition.

Methods: An electronic search was conducted using five databases and 6 relevant journals. Inclusion criteria were: Randomized Controlled Clinical Trials (RCTs), Controlled Clinical Trials (CCTs), cohort studies and case-control studies of children in the mixed dentition requiring a space maintainer or a space regainer, children with mild to moderate crowding, and with Class I and mild Class II or Class III skeletal pattern.

Results: Following the three phases of a systematic search, 11 were included for the final analysis, of which 1 article was found to be of critical risk, 2 articles of serious risk and 8 articles of moderate risk of bias.

Conclusions: Space maintainers may preserve arch length and prevent crowding in mildly to moderately crowded cases, but at the cost of proclination of the lower incisors. Space regainers were somehow effective in distalizing the maxillary and mandibular first permanent molars and thus contributing to the resolution of mild to moderate crowding in the mixed dentition. However, considering the low evidence provided by this systematic review, high-quality studies are needed.

Registration: PROSPERO (CRD42020170035).

Background

Dental crowding is defined as malalignment of teeth in the upper or lower arch. It can be classified according to the time of appearance as primary, secondary, and tertiary. Primary crowding is generally of genetic origin, where there is discrepancy between the tooth size and arch size. Secondary crowding is acquired and occurs due to premature loss of primary teeth, especially molars, which in turn leads to consequent loss of arch length. Tertiary crowding, also known as late incisor crowding, can occur towards the end of the peak of the mandibular growth [1].

Crowding in the permanent dentition due to premature loss of deciduous teeth for various reasons is one of the most common problems encountered by patients [2]. Dental crowding may have damaging effects on the oral health such as: difficulty in maintaining an optimal oral hygiene that may later lead to periodontal problems, aesthetic concerns and development of low self-esteem, and the prevention of an ideal occlusion [1, 3, 4]. In order to prevent malocclusion, specifically in patients with potential future secondary crowding, the best option is to maintain arch space by placing a space maintainer [5]. Space maintainers of all types are commonly used in the maxillary and mandibular arches to help maintain arch length following extraction of a deciduous tooth and to minimize the need for any orthodontic treatment in the future [6].

The term space maintenance was first used in 1941 by Brauer [7] and described as the process of maintaining a space in a dental arch previously occupied by a tooth or a group of teeth. Hence, a space maintainer is a device, that can be fixed or removable, mainly utilized to maintain the space created by the lost deciduous tooth or teeth until the eruption of their successors [8]. This is achieved by inhibiting the migration of the teeth adjacent to the edentulous span towards it, thus allowing normal eruption of the permanent successor [9].

Although fixed space maintainers, such as band-loop space maintainers, crown-loop space maintainers, lower lingual holding arch space maintainers, transpalatal arch space maintainers, and Nance appliances are used more commonly; different types of removable partial dentures have also been used.

When space loss does occur, space regainers can be used to help regain the space and allow for the prevention of any malocclusion that may occur later during dental development, including crowding. Space regaining in the maxillary arch can be achieved by molar distalization using different methods [10]. In the lower arch, space regaining can also be achieved, but much more difficult than in the upper arch, and is primarily obtained with the use of lip bumper devices. These devices help achieve molar distalization by distal repositioning and tipping of the molars which can lead to reduction in crowding by utilizing the space gained [11].

By reviewing the published literature on this topic, this systematic review aimed to address the clinical effectiveness of space maintainers and space regainers in the prevention and correction of dental arch decrease in the mixed dentition stage.

Methods

To aid in developing a well-structured design, PICO-S methodology was used in this systematic review as follows:

Population – children in the mixed dentition who require a space maintainer or a space regainer with mild to moderate crowding and Class I or mild Class II or mild Class III skeletal pattern.

Intervention – all types of space maintainers and all types of space regainers

Comparison – participants not receiving treatment

Outcome – The primary outcome was arch length changes in millimeters (mm) after the placement of a space maintainer or a space regainer

Secondary outcome measures were: the changes in the upper and lower incisor crowding in millimeters (mm) after the placement of a space maintainer or a space regainer. Crowding was measured as tooth size/ arch length discrepancy (TSALD) or using Little's irregularity index (LII). Other secondary outcome measures were: dental arch dimension changes in millimeters (inter-canine width, inter-molar width and arch depth) and proclination of the lower incisors.

Study design – Randomized controlled clinical trials (RCTs), controlled clinical trials (CCTs), prospective and retrospective longitudinal studies (cohort studies) and cross-sectional case-control studies.

Protocol and registration

This systematic review was conducted following the PRISMA guidelines [12] and registered *a priori* in Prospero (International Prospective Register of Systematic Reviews) under the registration number CRD42020170035.

Information sources and search strategy

A comprehensive search was carried out for both electronic databases and most relevant journals to minimize the possibility of excluding relevant studies by chance. The online databases used were: Cochrane Database for Systematic Reviews, EBSCO Host, ScienceDirect, PubMed, and Scopus until February 2020. The following keywords were used:

("space maintain*" or "band and loop" or "lingual arch" or "Nance appliance" or "transpalatal arch" or "lip bumper" or "distal shoe" or "crown and loop" or "space gain*" or "space regain*" or "space expand*" or "space expansion") and crowding

The manual search included the following journals:

1. International Journal of Paediatric Dentistry (1998–2020)
2. The Journal of Clinical Pediatric Dentistry (2006–2020)
3. Journal of Orthodontics (2003–2019)
4. European Journal of Orthodontics (1996–2020)
5. The Angle Orthodontist (2005–2020)
6. American Journal of Orthodontics and Dentofacial Orthopedics (1986–2020).

Data extraction was carried out using a Cochrane data extraction form for RCTs and Non-RCTs by four investigators independently and then the collected information was agreed on by all of them. Data extracted included sample size, gender, number of dropouts, type of space maintainer or space regainer used, amount of crowding present before the start of treatment, duration of the treatment/ follow-up period, amount of space gained when using space regainers, and the amount of space loss in control groups. For studies that did not have a control group, data was extracted to compare measurements before and after the placement of space maintainers or space regainers. For any study that included multiple treatment groups, only the treatment groups that used space maintainers or space regainers was considered and compared to the control group who received no treatment.

Eligibility criteria

Articles were comprehensively screened for (1) children in the mixed dentition, (2) children who require a space maintainer or a space regainer, (3) children with mild to moderate crowding, (4) children with Class I or mild Class II or mild Class III skeletal pattern. All

articles involving patients with a previous history of orthodontic treatment/orthognathic surgery, patients with moderate or severe skeletal discrepancy, case series, case reports, other study designs that are not eligible, articles not in English, and animal studies were excluded. Studies were first excluded based on titles and abstracts followed by the assessment of full texts. This was done by two teams of investigators independently and met thereafter to agree the outcome of the search. References of all included articles were searched to further identify possible studies for inclusion according to the inclusion criteria.

Risk of bias and quality assessment

The quality of all articles included in this review were assessed by two teams of investigators independently using the Cochrane risk of bias tools (RoB 2.0) [13] for RCTs and the ROBINS-I tool [14] for the other types of studies. These tools measure five domains including selection bias, detection bias, performance bias, reporting bias, and finally attrition bias in order to determine the level of bias of a certain article. Both tools are used to assess bias and the result is reported in a rating of low, moderate, high, and severe risk of bias of each domain. The GRADE (Grading of Recommendations, Assessment, Development and Evaluations) system was used to assess the overall quality of evidence for each outcome presented in this systematic review [15]. It has five domains of assessment namely: risk of bias, imprecision, inconsistency, indirectness, and publication bias. Studies were downgraded from a "high quality" score by one level for serious and two levels for very serious in these five domains.

Results

Study selection

The PRISMA chart (Fig. 1) shows the search process and the final number of included and excluded articles. The initial search resulted in 1,175 articles that were examined; 1,127 from electronic searches and 48 articles from manual searches. 360 articles were duplicates and 755 articles were excluded either due to not meeting the inclusion criteria or because they were not relevant to the study's topic. This left 60 articles to be assessed for inclusion. 49 of these articles were excluded due to various reasons such as, study designs, not in English and being duplicates with different titles. Finally, 11 articles were chosen to be included in this review. One of these articles was an RCT [16], one was a CCT study [17], 5 were case control studies [18–22], 4 were cohort studies [23–26], with two being a retrospective study [23, 26].

The search process was done independently by two teams of investigator and then they met to form an agreement regarding the outcome of the search.

Risk of bias within studies

The risk of bias for the eleven included articles was assessed using the RoB 2.0 and ROBINS-I tools and summarized in Figs. 2, 3 & 4. When assessing risk of bias using ROBINS-I tool for the 10 non-RCT studies, 1 article was found to be of critical risk, 2 articles of serious risk and 7 articles of moderate risk of bias. The RCT article was deemed to have some concerns/moderate risk of bias (RoB 2.0)

Results of individual studies

Space maintainers

In total, nine studies on space maintainers were included in this systematic review. The results of these studies showed mixed findings regarding the preservation of arch length. Four of the 8 articles that focused on space maintainers showed that the use of lower lingual arch devices was effective in increasing arch length [16, 18, 19, 26]. However, the four other articles that used lower lingual arch space maintainers reported a decrease in arch length following the placement of space maintainer devices [17, 21, 24, 25]. Of these, only one study on space maintainers measured crowding as tooth size/arch size discrepancy [24]. The last study [22] found that removable lower space maintainers might stop the increase in intercanine arch width and perimeter, which is undesirable (Table 1).

Table 1
Summary of data from studies included in this review that reported changes in arch length

Study details	Study design	Sample size	Participants details (gender, age, and dropouts)	Type of crowding of participants	Type of intervention	Outcome measures	Follow-up period	Results
Owais et al. (2010) [16]	Randomized clinical trial	N = 67	Group 1: 20 Subjects (12 males and 8 females, average age: 10.76 ± 0.75). Group 2: 24 subjects (12 males and 12 females, average age: 10.58 ± 0.54). Control group: 23 subjects (15 males and 8 females), average age: 10.63 ± 0.66). No. of dropouts: 9	Mild lower anterior crowding (less than 2 mm).	Lower lingual holding arch with 0.9 mm stainless steel wire for group 1 and 1.25 mm stainless steel wire for group 2.	Arch length measured using Boley caliper to the nearest 0.5 mm.	Not reported	Group 1: arch length increased by 0.53 ± 0.73. Group 2: arch length decreased by 0.98 ± 0.28. Control group: arch length increased by 0.16 ± 0.33.
Fichera et al. (2011) [18]	Case-control study	N = 60	Cases group: 48 patients, average age: 9 ± 0.8 years. Control group: 18 patients (8 males and 10 females), average age: 9.2 ± 0.6 years. No. of dropouts: 0	Not reported	Lingual arch with 0.9 mm stainless steel rounded wire.	Arch length measured using brass wire and then calculated by digital calipers and recorded to the nearest 0.02 mm	Not reported	Cases Group: arch length increased by 0.04 mm Control group: arch length decreased by 1.8 mm

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Study details	Study design	Sample size	Participants details (gender, age, and dropouts)	Type of crowding of participants	Type of intervention	Outcome measures	Follow-up period	Results
Ciftci et al. (2018) [17]	Controlled clinical trial	N = 34	Group 1 (unilateral tooth loss): 8 males and 8 females, average age: 8.8 ± 0.9 years. Group 2 (bilateral tooth loss): 10 males and 8 females, average age: 8 ± 0.7 years. No. of dropouts: 0	Not reported	Lingual arch with 0.9 mm stainless steel wire.	Arch length measured on study casts	Not reported	Group 1: total arch length decreased by 0.4 mm. Group 2: arch length increased by 0.9 mm.
Nevant et al. (1991) [23]	Retrospective cohort study	N = 40	Group 1: 20 patients, average age 11 years. No. of dropouts: 8 Group 2: 20 patients, average age 12.1 years. No. of dropouts: 10	Moderate crowding (4–8 mm)	Lip bumpers with 1.14 mm stainless steel round wire covered with a layer of plastic shrink tubing for group 1, and prefabricated lip bumpers that had a relatively thick shield of acrylic from canine to canine for group2.	Arch length measured on dental casts with electronic dial calipers to the nearest 0.01 mm.	Group 1: 1.4 years. Group 2: 1 year.	Group 1: total arch length increased by 2.7 mm/ year. Group 2: total arch length increased by 7.45 mm/ year.
Rebellato et al. (1997) [19]	Case-control study	N = 30	Cases group: 14 patients, average age: 11.5 years). Control group: 16 patients, average age: 11.3 years). No. of dropouts: 0	Crowding of ≥ 3 mm	Lingual arch with 0.81 mm stainless steel wire, which contacted the cingulae of the lower incisors.	Arch length measured to the nearest 0.02 mm.	Cases group: 10.5 months. Control group: 12.5 months.	Cases group: arch length increased by 0.07 mm. Control group: arch length decreased by 2.54 mm.

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Study details	Study design	Sample size	Participants details (gender, age, and dropouts)	Type of crowding of participants	Type of intervention	Outcome measures	Follow-up period	Results
Raucci et al. (2015) [20]	Case-control study	N = 56	Cases group: 14 males and 22 females, age was ≤ 9 years. Control group: 10 males and 10 females, age was ≤ 9 years. No. of dropouts: 0	Mild to moderate maxillary crowding	A prefabricated transpalatal arch with 0.9 mm stainless steel wire with a mesially directed loop in the middle	Arch length measured using digital calipers Crowding was measured as tooth-size/total-arch discrepancy	3 years after the end of treatment with roughly 2 years of passive retention using Hawley retainers in the maxillary arch.	Arch length changes were not significant in both cases and control groups. Cases group: crowding decreased by 4.18 mm. Control group: crowding increased by 1.6 mm.
Brennan et al. (2000) [24]	Cohort study	N = 107	Study group: 43 males and 64 females, average age 8.6 years (range: 7 to 11 years). No. of dropouts: 0	Mandibular incisor crowding	Lingual arch with 0.9 mm stainless steel wire, which contacted the cingulum region of the incisors and soldered to the lingual surfaces of the first molar bands.	Arch length measured using digital calipers to the nearest 0.01 mm. Crowding was identified as tooth size-arch size discrepancy.	Not reported	Arch length decreased by 0.44 mm ± 1.35 mm. Average amount of incisor crowding resolved was 5.0 ± 2.1 mm and it decreased in 105 of the 107 patients.

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Study details	Study design	Sample size	Participants details (gender, age, and dropouts)	Type of crowding of participants	Type of intervention	Outcome measures	Follow-up period	Results
De Baets et al. (1995) [25]	Cohort study	N = 39	Group 1: (9 patients)- well-aligned lower arch with multiple diastemas, revealing an excess of space. Group 2: (16 patients)- well-aligned incisors, with all teeth in contact. Group 3: (12 patients)- considerable remaining crowding, indicating the need for extractions. Group 4: (2 patients)- occlusal interferences preventing proper alignment of the teeth, even though space was available. No. of dropouts: 0	Crowding only mentioned as "lower incisor crowding".	Passive lingual arches	Mandibular arch length measured using a dial caliper on plaster casts.	5 years following retention for only an example of 1 patient.	Group 1: arch length decreased by 1.24 ± 0.74 mm. Group 2: arch length decreased by 0.79 ± 0.97 mm. Group 3: arch length decreased by 0.23 ± 1.28 mm. Group 4: arch length decreased by 1.15 ± 1.63 mm.
Dugoni et al. (1995) [26]	Retrospective cohort study	N = 25	Study Group: 13 patients with class I occlusion (5 males and 8 females) and 12 patients with class II occlusion (3 males and 9 females). No. of dropouts: 0	Mandibular anterior crowding of ≥ 3 mm.	Lingual arch appliance used was a removable, Unitek, Monrovia, Calif with 0.76 mm stainless steel wire and an adjustment loop.	Arch length measured using dial calipers on casts to the nearest 0.01 mm.	9.5 years with a range of 5 to 22 years.	Arch length increased by 0.33 ± 2.65 mm in the treatment group (T1-T2).

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Study details	Study design	Sample size	Participants details (gender, age, and dropouts)	Type of crowding of participants	Type of intervention	Outcome measures	Follow-up period	Results
Miotti (1984) [21]	Case-control study	N = 63	Cases group: 33 patients (12 males and 21 females), average age of 12.0 years. Control group: 30 patients (11 males and 19 females), average age of 11.8 years. No. of dropouts: 0	Not reported	Lower lingual arch adapted as a passive space maintainer.	Tracings were made on the lateral radiographs and arch length changes were measured at the CEJ level of the incisors and molars and from the incisal edge to the mesial molar cusp	Not reported	Cases group: arch length decreased by 1.22 ± 1.7 mm at the crown level and 1.6 ± 1.4 mm at the CEJ level. Control group: arch length decreased by 3.0 ± 1.5 mm at the crown level, and 1.9 ± 1.3 mm at the CEJ level.
Dincer et al. (1996) [22]	Case-control study	N = 20	Cases group: 10 patients, average age of 9 years and 5 months. Control group: 10 patients, average age of 9 years and 7 months. No. of dropouts: 0	Not reported	Removable lower space maintainer	Arch length measured on dental casts which were taken before treatment and after eruption of permanent canines.	Not reported	Cases group: arch length decreased by 1.4 mm in intercanine perimeter. Control group: arch length increased by 4 mm in intercanine perimeter.
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Space regainers

Only two studies on space regainers met the inclusion criteria and were included in this systematic review [20, 23]. One study used a lip bumper and found that they were significantly effective in increasing the arch length [23]. The other study investigated the effect of transpalatal arch devices on increasing arch length in the maxilla [20]. They found that while the transpalatal arch devices decreased arch length, it was significantly effective in reducing dental crowding in the maxillary arch (Table 2).

Table 2
Summary of data from studies included in this review that reported changes in crowding only

Study	Intervention used	Results of the treatment group(s) (mean ± SD)	Results of the control group(s) (mean ± SD)	Significance of results (P-value)
Raucci et al. (2015) [20]	Maxillary transpalatal arch	-4.3 ± 1.97 mm	1.63 ± 2.45 mm	Significant between the treatment and control groups and in the same group before and after treatment (P< 0.0001)
Brennan et al. (2000) [24]	Lower lingual arch	5.0 ± 2.1 mm	NA	Not reported

Evaluating the strength of evidence provided by this review

According to the GRADE system, the overall quality of evidence provided by this review was judged to be low for both outcome measures i.e. arch length and dental crowding due to the following factors: moderate to critical risk of bias across the included studies, small sample sizes investigated by the majority of studies, non-significant findings from clinical point of view as well as conflicting findings reported by some included studies (Table 3).

Table 3
A summary of GRADE's approach to rating the overall quality of evidence

No. of participants	Risk of bias	Indirectness	Imprecision	Inconsistency	Publication bias	Overall quality of evidence
Changes in arch length						
541	Serious	Not serious	Borderline serious	Serious	Not suspected	Low ⊕⊕□□
Changes in crowding						
188	Serious	Not serious	Borderline serious	Serious	Not suspected	Low ⊕⊕□□
Legends of Figures						

Discussion

The present systematic review was performed to analyze the effectiveness of space maintainers and space regainers in the prevention and correction of dental arch decrease in the mixed dentition. Despite their common use, there is limited evidence regarding their effectiveness on arch length changes and potential crowding in the future [16].

Comparisons with previous systematic reviews

There have been two systematic reviews that evaluated the effect of the lower lingual arch (LLA) only without including other types of space maintainers and space regainers [27, 28]. Therefore, the present review is the first study to assess effectiveness of all types of space maintainers and space regainers in arch length measurements and alignment of teeth. A systematic review by Viglianisi et al, in 2010 investigated the effect of a LLA on the mandibular arch dimensions, showed that the LLA is effective in preventing a loss of arch length and tipping of the molars [27]. This result contrasts the findings of 4 out of the 9 articles included in our review that reported a decrease in arch length following the placement of a LLA [17, 21, 24, 25]. However, Viglianisi's review [27] included only two longitudinal clinical studies and lacked control groups, thus it was difficult to make a proper comparison with our systematic review. On the other hand, a second systematic review and meta-analysis conducted by Chen et al, in 2019 found that a LLA increased the intercanine and intermolar width significantly [28], a finding which is consistent with the findings of the present systematic review. Chen et al, also reported a non-significant increase in arch length and that a LLA resolved mandibular incisor crowding and prevented incisors from tipping.

Effect of different space maintainers/ regainers on total arch length

The lower lingual arch is a commonly used device to maintain arch length and to prevent mesial migration of the lower first permanent molars after early extraction or loss of the lower primary second molars. Most articles included in our systematic review found that a lower lingual holding arch (LLHA) tended to cause proclination and forward movement of the mandibular lower incisors which may have contributed to preservation of the arch length. Other studies in our review also found that arch length would be preserved whilst using a lower lingual holding arch space maintainer [16–18].

One study showed a decrease in total arch length of 2.54 mm in the control group, who did not receive any kind of treatment. Whereas, the treatment group, who only received a mandibular lingual arch appliance, had a slight increase of 0.07 mm [19].

On the other hand, Brennan et al. [24] reported an average decrease in arch length by 0.44mm in 62 patients out of 107 (57.9%) following the placement of a lower lingual arch space maintainer, while arch length increased in 39 patients (36.4%) and remained the same in 6 patients (5.6%). He theorized that the variation in arch length changes between patients could be attributed to the incisor position, molar position, and facial growth which means that the LLA could have un-anticipated results in the impact on arch length in certain patients.

De Baets et al. [25] reported an average decrease in arch length by 1mm and a maximum of 2.3mm following the placement of a lower lingual arch, which can be explained by movement of the labially inclined incisors to a more harmonious lingual position. On the contrary, a study by Dugoni et al. [26] investigating the effectiveness of a lower lingual arch on arch length in a cohort of 25 patients, showed that the mandibular arch length did not decrease during the mixed dentition, but it decreased during the post-retention phase. However, this decrease in arch length after treatment with a lower lingual arch, was found to be not significant when compared with the control group by Miotti [21].

With regards to the use of a lip bumper as a space maintainer/ regainer, it was found that patients who received prefabricated lip bumpers with relatively thick shields extending from canine to canine had a mean annual increase of 7.45mm/year in total arch length in comparison with patients who received lip bumpers that were fabricated from 0.045-inches stainless steel round wire, with an annual change of 2.66m/year in the total arch length [23].

The changes found in arch length following the use of a transpalatal arch appliance seems to differ from those produced with a lip bumper, where it was shown that the former caused an increase of 4.3mm in total arch length compared to no significant changes in dental arch perimeter in the control group [20].

The majority of studies included in our review found a significant increase in intermolar, intercanine and interpremolar arch width after placing a space maintainer [16, 17, 19, 20, 24, 26]. One reason for the increase in the intercanine width found in the aforementioned studies was the lateral migration of canines into the leeway space and developmental changes in arch dimension; [16, 18] an explanation which was further supported by the finding that removable space maintainers resulted in an increase in the intercanine arch width when transitioning between primary and permanent canines [22]; while the increase in the inter-molar width was most probably attributed to biological mechanisms [17].

Effect of different space maintainers/ regainers on crowding

The literature search yielded three relevant studies in which the effect of a passive lingual arch on resolving mandibular incisor crowding was evaluated during the mixed dentition stage in a total of 188 patients. Out of the 188 cases, 161 patients (86%) had a decrease in the mandibular incisor crowding after the LLA treatment [20, 24, 26].

Brennan and Gianelley24 found that a complete preservation of the arch length could result in an increase in the percentage of crowding resolution due to the approximate addition of 0.5 mm of space. Dugoni et al. [26], reported that early treatment with a LLA could result in a better incisor stability in the post-retention period, as early treatment allows ideal incisor alignment at a young age. This proper alignment is held in place by the LLA until all permanent teeth erupt. Therefore, incisors retain their previous crowded position only for a short period of time. Moreover, supracrestal fibers were able to reorganize and hold the incisors in their proper alignment at an early age.

With regards to the effectiveness of the trans-palatal arch; a relief of crowding was reported by a mean of 4.18 mm in the treatment group, while the untreated control group had an increase in the amount of crowding by a mean of 1.6 mm [20]. These results support the use of a space maintainer in order to prevent and decrease crowding in the mixed dentition.

Clinical relevance and implications for future research

Overall, using a space maintainer may help reduce arch perimeter loss during the transition from the mixed to the permanent dentition [19]. It seems that a lower lingual arch space maintainer made of a 0.9 mm diameter stainless steel archwire is associated with a fewer problems than similar archwires, but of larger diameter (1.25 mm) [16]. It was also found that a lower lingual arch was more effective when it was used unilaterally, and produced better results than if it was used bilaterally [17]. Moreover, it may be preferable to use prefabricated lip bumpers with thick acrylic sheets than other types, as the formers have larger surface areas of plastic, thus have the potential of generating greater forces on the molars and bringing about more distal movement [23].

Future studies should be consistent in reporting similar and relevant outcome measures arch dimension changes and should include untreated control group to facilitate comparisons and allow pooling the findings in meta-analyses to improve the certainty of the findings.

Limitations

Certain limitations must be acknowledged when interpreting the findings of our systematic review. There was a lack of well-designed randomized clinical trials to be included in the current review as only one RCT met the inclusion criteria and thus was included. Regarding the remaining 10 non-RCT studies included in this review, only half of them have untreated control groups. In addition, even though the studies had a fairly balanced variation in gender, 4 out of 10 studies did not specify the gender of the participants, which could affect the results. Furthermore, the majority of studies were heterogeneous in terms of their designs, type of space maintainer/ gainer, reported outcome measures and risk of bias. As a consequence, it was not possible to combine the findings of the included studies in a meta-analysis.

Conclusions

Within the limitations of this systematic review the following conclusions may be drawn:

1. Lower lingual arch space maintainers are likely to be effective in preserving arch length in patients during the mixed dentition stage.
2. Lip bumpers and transpalatal arch devices are likely to be successful in maintaining arch length during the mixed dentition.
3. Arch length preservation using lingual arches could be sufficient to prevent lower incisor crowding, and similarly transpalatal arch devices could be adequate to prevent maxillary crowding during the mixed dentition stage in most patients.
4. High-quality well-designed studies are required to be able to form more definitive conclusions.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

RCTs: Randomized Controlled Clinical Trials; **CCTs**: Controlled Clinical Trials; PICO-S: Participants, Interventions, Comparisons, Study design; **PROSPERO**: International prospective register of systematic reviews; **TSALD**: tooth size/ arch length discrepancy; **LII**: Little's irregularity index; **PRISMA**: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; **RoB**: Risk of Bias; **GRADE**: Grading of Recommendations, Assessment, Development and Evaluations; **LLA**: lower lingual arch; **LLHA**: lower lingual holding arch; CEJ: Cementoenamel Junction.

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Figures
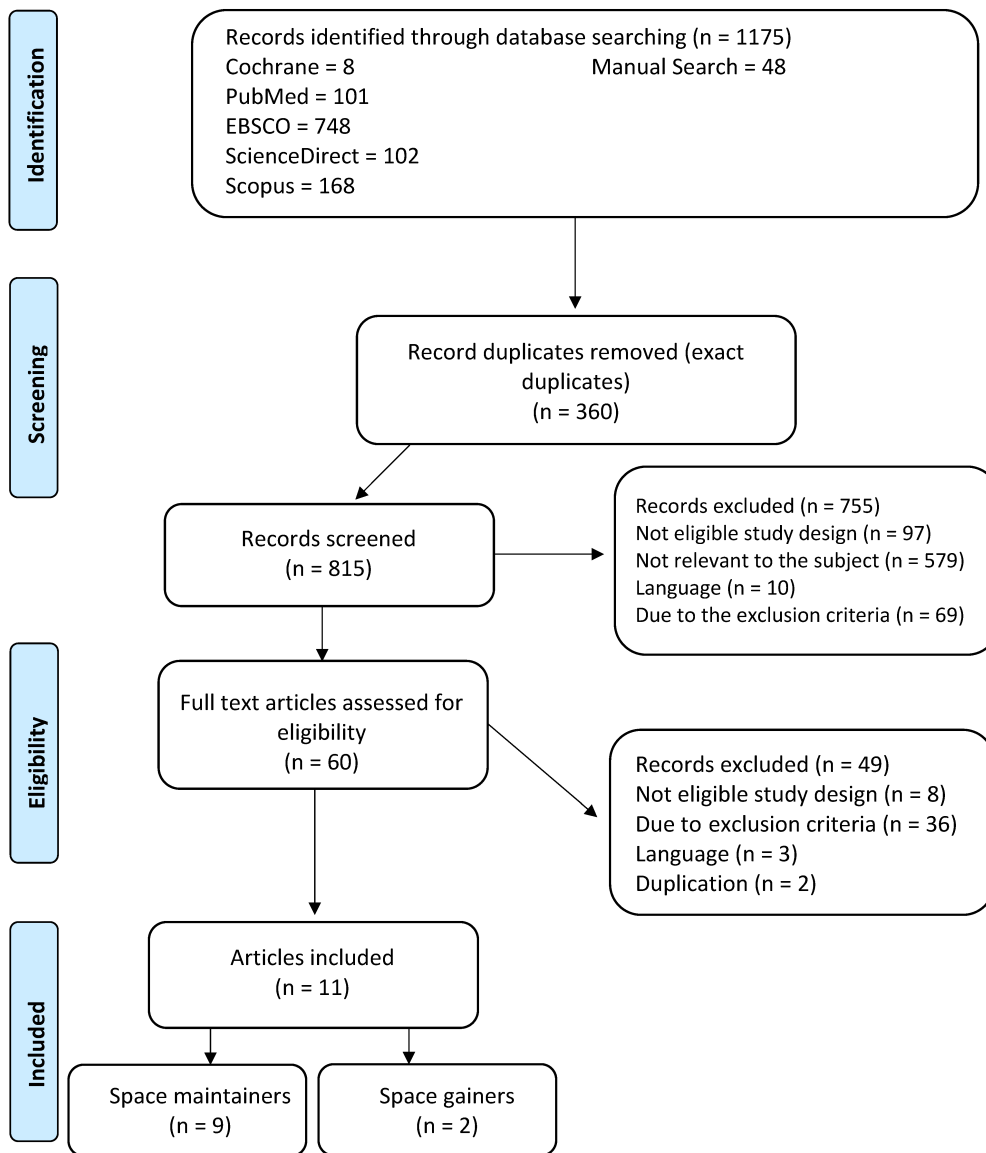
Figure 1

Flow diagram of study identification and selection using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Risk of bias domains

Study	D1	D2	D3	D4	D5	Overall
Owais et al. (2010)	−	+	−	+	+	−

Domains:
D1: Bias arising from the randomization process.
D2: Bias due to deviations from intended intervention.
D3: Bias due to missing outcome data.
D4: Bias in measurement of the outcome.
D5: Bias in selection of the reported result.

Judgement
− Some concerns
+ Low

Figure 2

Risk of Bias Assessment for the RCT included in this review

Risk of bias domains

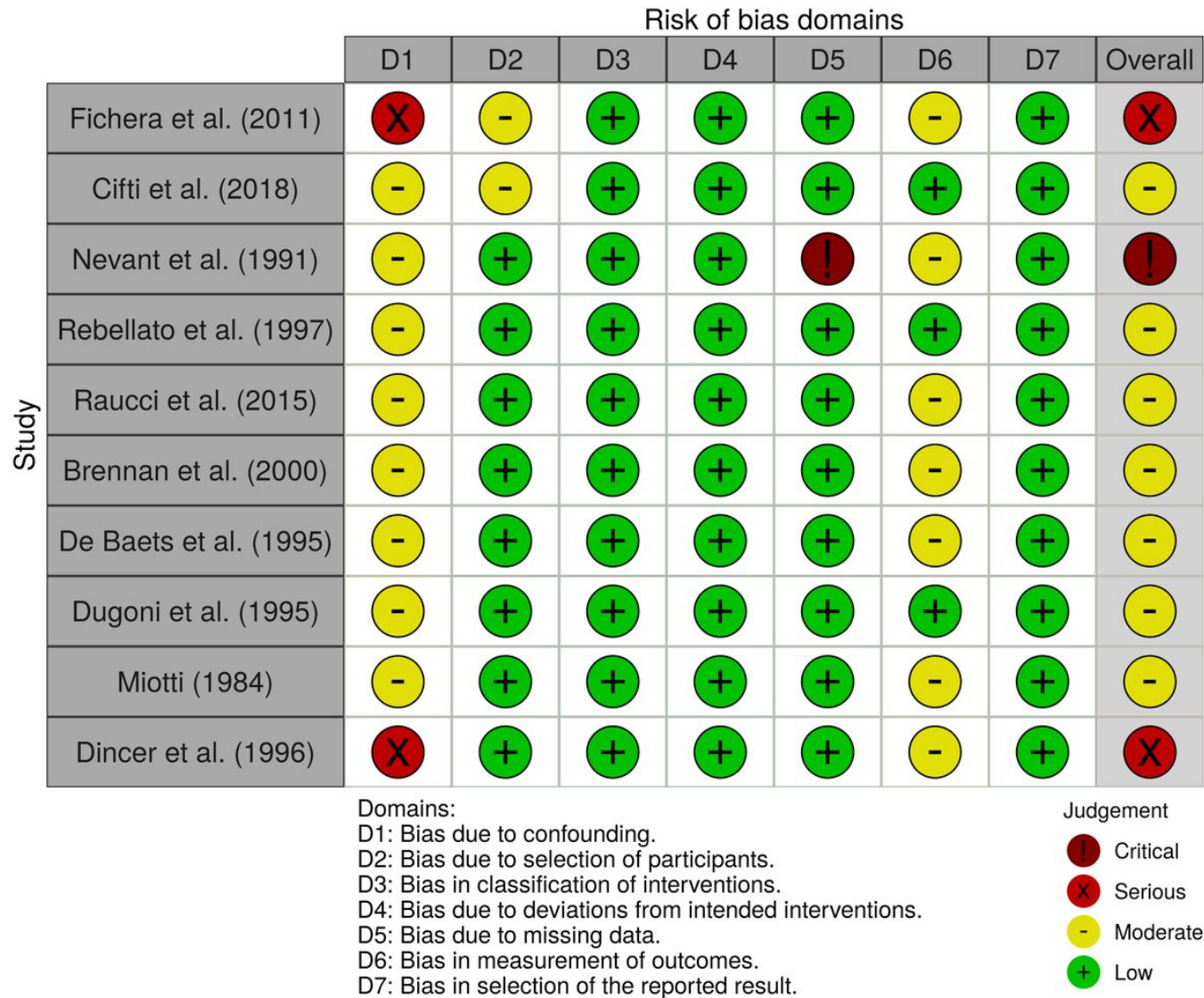| Study	D1	D2	D3	D4	D5	D6	D7	Overall
Fichera et al. (2011)	✗	−	+	+	+	−	+	✗
Cifti et al. (2018)	−	−	+	+	+	+	+	−
Nevant et al. (1991)	−	+	+	+	!	−	+	!
Rebellato et al. (1997)	−	+	+	+	+	+	+	−
Raucci et al. (2015)	−	+	+	+	+	−	+	−
Brennan et al. (2000)	−	+	+	+	+	−	+	−
De Baets et al. (1995)	−	+	+	+	+	−	+	−
Dugoni et al. (1995)	−	+	+	+	+	+	+	−
Miotti (1984)	−	+	+	+	+	−	+	−
Dincer et al. (1996)	✗	+	+	+	+	−	+	✗

Domains:
D1: Bias due to confounding.
D2: Bias due to selection of participants.
D3: Bias in classification of interventions.
D4: Bias due to deviations from intended interventions.
D5: Bias due to missing data.
D6: Bias in measurement of outcomes.
D7: Bias in selection of the reported result.

Judgement
! Critical
✗ Serious
− Moderate
+ Low

Figure 3

Risk of Bias Assessment for the other studies included in this review

Bias due to confounding
Bias due to selection of participants
Bias in classification of interventions
Bias due to deviations from intended interventions
Bias due to missing data
Bias in measurement of outcomes
Bias in selection of the reported result
Overall risk of bias

0% 25% 50% 75% 100%

Low risk Moderate risk Serious risk Critical risk

Figure 4
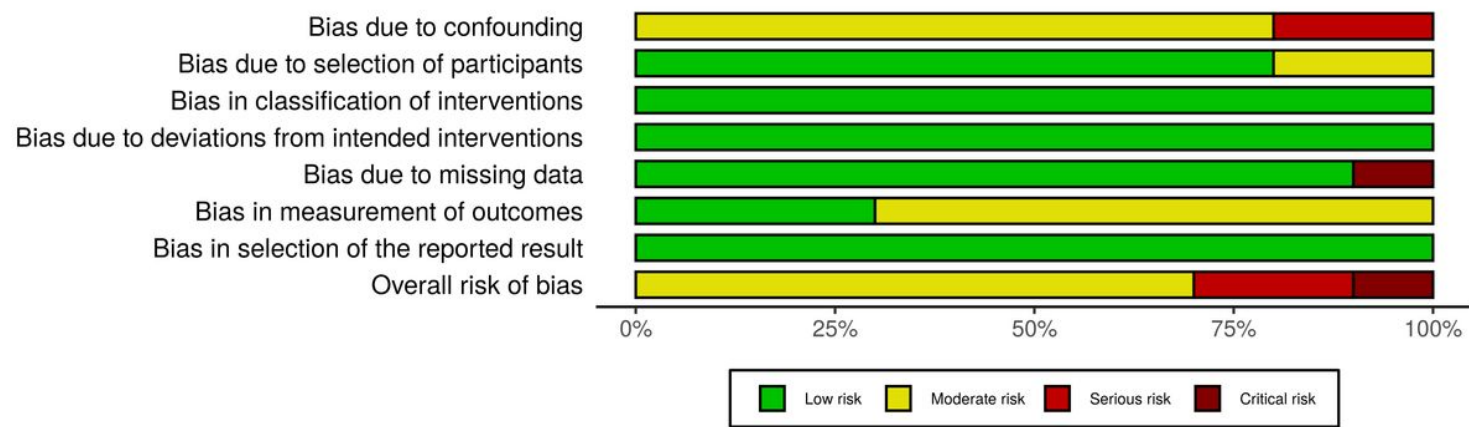
Summary of the Percentage Allocation of Risk of Bias Grades in each Domain Across the 10 non-RCT studies