Saudi Dental Journal (2022) **34**, 75–86

King Saud University

Saudi Dental Journal

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REVIEW ARTICLE

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

Khaled Khalaf *, Aseel Mustafa, Mohammad Wazzan, Mennatalla Omar, Mohammed Estaitia, Mohamed El-Kishawi

Department of Preventive and Restorative Dentistry, College of Dental Medicine, University of Sharjah, United Arab Emirates

Received 30 June 2021; revised 21 September 2021; accepted 29 September 2021
Available online 9 October 2021

KEYWORDS

Distalizing;
Appliances;
Agenesis;
Pediatric dentistry;
Space Maintenance;
Crowding

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 decreases in mixed dentition.

Methods: An electronic search was conducted using five databases: the Cochrane Database for Systematic Reviews, EBSCO Host, ScienceDirect, PubMed, and Scopus (until February 2021) 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. All articles included in this review were examined independently by three teams of investigators to assess the level of bias using the Cochrane risk of bias tools RoB 2.0 (for RCTs) and ROBINS-I (for non-RCTs).

Results: Following the three phases of a systematic search, 11 studies were included for the final analysis, of which nine used space maintainers (a lower lingual arch) and two used space regainers (one lip bumper and one transpalatal arch) with contradicting results. Four of the former and one of the latter devices showed a significant increase in arch length. Out of the 11 articles, one was found to be of critical risk, two of serious risk and eight of moderate risk of bias.

Conclusions: There is very low evidence to suggest that space maintainers and regainers are effective in preserving arch length and preventing mild to moderate crowding in children during the

* Corresponding author at: Preventive and Restorative Dentistry Department, College of Dental Medicine, Building M28, University of Sharjah, Sharjah, United Arab Emirates.
E-mail address: kkhalaf@sharjah.ac.ae (K. Khalaf).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sdentj.2021.09.025

mixed dentition stage at the expense of lower incisor proclination. However, considering the low evidence provided by this systematic review, high-quality studies are needed.

Contents

1. Introduction

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 a 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 lower incisor crowding, can occur toward the end of the peak of mandibular growth (Proffit et al., 2018).

Crowding in the permanent dentition due to premature loss of deciduous teeth is one of the most common problems encountered by patients (Jitesh and Mathew, 2019). Dental crowding may have damaging effects on oral health, such as difficulty maintaining optimal oral hygiene, which may later lead to periodontal problems, aesthetic concerns and the development of low self-esteem, and the prevention of an ideal occlusion (Caplin et al., 2015; Anthony et al., 2018; Proffit et al., 2018). To prevent malocclusion, specifically in patients with potential future secondary crowding, the best option is to maintain arch space by placing a space maintainer (Wright and Kennedy, 1978). 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 (Bijoor and Kohli, 2005).

The term space maintenance was first used in 1941 by (Brauer, 1941) and described as the process of maintaining 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 and is mainly utilized to maintain the space created by the lost deciduous tooth or teeth until the eruption of their successors (Singh et al., 2020). This is achieved by inhibiting the migration of the teeth adjacent to the edentulous span toward it, thus allowing normal eruption of the permanent successor (Gianelly, 1995).

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 (Chandak et al., 2015). In the lower arch, space regaining can also be achieved but is 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 a reduction in crowding by utilizing the space gained (Davidovitch et al., 1997).

There is a lack of consensus on the clinical effectiveness of space maintainers and regainers. Furthermore, previous systematic reviews on the subject have evaluated the effect of only one type of space maintainer (the lower lingual arch (LLA)) (Viglianisi, 2010; Chen et al., 2019). By reviewing the up-to-date published literature on this topic, this systematic review aimed to address the clinical effectiveness of all types of space maintainers and space regainers in the prevention and correction of dental arch decrease in the mixed dentition stage. Therefore, this will help to inform clinicians on the value of early orthodontic interventions in children with premature loss of primary molars to decrease the severity of future crowding, the complexity of future orthodontic interventions and the time and cost of future treatments.

2. 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; the same patients before and after receiving treatment.

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

The secondary outcome measures were the changes in the upper and lower incisors 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 (intercanine width, intermolar 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.

2.1. Protocol and registration

This systematic review was conducted following the PRISMA guidelines (Moher et al., 2009) and registered *a priori* in Prospero (International Prospective Register of Systematic Reviews) under the registration number CRD42020170035. At the time of registering the study protocol, the primary outcome measure was the changes in the upper and lower incisor crowding. However, following completion of the search, the majority of studies reported the primary outcome measure as dental arch length changes; therefore, it was more appropriate to synthesize the included studies to change the primary outcome measure as dental arch length changes and consider the changes in the upper and lower incisor crowding as secondary outcome measures.

2.2. Information sources and search strategy

A comprehensive search was carried out for both electronic databases and most relevant journals as well as the gray literature to minimize the possibility of excluding relevant studies by chance. The online databases used were the Cochrane Database for Systematic Reviews, EBSCO Host, ScienceDirect, PubMed, and Scopus until February 2021. 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 Pediatric Dentistry (1998–2021)
2. The Journal of Clinical Pediatric Dentistry (2006–2021)
3. Journal of Orthodontics (2003–2021)
4. European Journal of Orthodontics (1996–2021)
5. The Angle Orthodontist (2005–2021)
6. American Journal of Orthodontics and Dentofacial Orthopedics (1986–2021).

2.3. Eligibility criteria

Articles were comprehensively screened for (1) children in the mixed dentition, (2) children who required a space maintainer or a space regainer, (3) children with mild to moderate crowding, and (4) children with Class I or mild Class II or mild Class III skeletal patterns. 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 were not eligible, 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 who met thereafter to agree on the outcome of the search, and in the case of such agreement not reached, this was decided by a third reviewer. References of all included articles were searched to further identify possible studies for inclusion according to the inclusion criteria.

2.4. Data extraction

Data extraction was carried out using a Cochrane data extraction form for RCTs and non-RCTs by three investigators independently, and then the collected information was agreed upon 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 were 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 were considered and compared to the control group who received no treatment.

2.5. Risk of bias and quality assessment

The risk of bias of all articles included in this review was assessed by two teams of investigators independently using the Cochrane risk of bias tools (RoB 2.0) (Higgins et al., 2016) for RCTs and the ROBINS-I tool (Sterne et al., 2016) for the other types of studies. RoB 2.0 measures five domains, namely, randomization bias, bias due to deviation from intended intervention, missing outcome data, measurement of the outcome and finally the selection of the reported outcomes, while ROBINS-I measures seven domains, namely, bias due to confounding, bias in selection of participants of the study, bias in the classification of the intervention, bias due to deviations from the intended interventions, bias due to missing data, bias of measurements of the outcome and finally bias in selection of the reported results. Both tools were used to assess bias, and the results were reported in a rating of low, moderate, serious, and critical risk of bias of each domain for the ROBINS-I tool and low, some concerns, and high for the RoB 2.0 tool.

2.6. Data synthesis strategy

A descriptive (narrative) analysis of the data was carried out, as it was not possible to analyze the data quantitatively using a *meta*-analysis due to the dissimilarities of the included studies in terms of their designs, type of space maintainer/regainer, reported outcome measures, follow-up periods and low risk of bias.

2.7. Assessment of quality of evidence presented by this review

The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system was used to assess the overall quality of evidence for each outcome presented in this systematic review (Guyatt et al., 2008). 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.

3. Results

3.1. Study selection characteristics

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. Three hundred and sixty articles were duplicates, and 755 articles were excluded either due to not meeting the inclusion criteria or because they were not relevant to the topic of the study. This left 60 articles to be assessed for inclusion. Forty-nine of these articles were excluded due to duplicates with different titles and other reasons, such as study designs, patients with a previous history of orthodontic treatment and patients with moderate or severe skeletal discrepancy. Finally, 11 articles were chosen to be included in this review, of which nine were about space maintainers (8 used LLA and 1 used a removable lower space maintainer) and two were about space regainers (1 used a lip bumper and the other used a transpalatal arch). One of these articles was an RCT (Owais et al., 2011), one was a CCT study (Ciftci et al., 2018), 5 were case control studies (Miotti, 1984; Dincer et al., 1996; Rebellato et al., 1997; Fichera et al., 2011; Raucci et al., 2015), and 4 were cohort studies (Nevant et al., 1991; De Baets and Chiarini, 1995; Dugoni et al., 1995; Brennan and Gianelly, 2000), with two being of a retrospective design (Nevant et al., 1991; Dugoni et al., 1995).

3.2. 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 the risk of bias using the ROBINS-I tool for the 10 non-RCT studies, 1 article was found to be of critical risk (Nevant et al., 1991), 2 articles of serious risk (Dincer et al., 1996; Fichera et al., 2011) and 7 articles of moderate risk of bias (Miotti, 1984; De Baets and Chiarini, 1995; Dugoni et al., 1995; Rebellato et al., 1997; Brennan and Gianelly, 2000; Raucci et al., 2015; Ciftci et al., 2018). The RCT article was deemed to have 'some concerns' risk of bias (RoB 2.0) (Owais et al., 2011).

3.3. Results of individual studies

The results of the individual studies will be summarized and reported narratively, as it was not possible to pool the findings in a *meta*-analysis due to the dissimilarities among the included studies in terms of their designs, type of space maintainer/regainer, reported outcome measures, and follow-up periods, and none of them was judged to be of low risk of bias.

3.3.1. Space maintainers

In total, nine studies on space maintainers were included in this systematic review, of which 8 used lower lingual arch devices and 1 used removable lower space maintainers. The results of these studies showed mixed findings concerning the preservation of arch length. Four of the 8 articles that used lower lingual arch devices showed that the use of these devices was effective in increasing arch length (Dugoni et al., 1995; Rebellato et al., 1997; Fichera et al., 2011; Owais et al., 2011), whereas the remaining four articles reported a decrease in arch length following the placement of lower lingual arch devices (Miotti, 1984; De Baets and Chiarini, 1995; Brennan and Gianelly, 2000; Ciftci et al., 2018). Of these, only one study on space maintainers measured crowding as a tooth size/arch size discrepancy (Brennan and Gianelly, 2000). The last study (Dincer et al., 1996) found that removable lower space maintainers might stop the increase in intercanine arch width and perimeter, which is undesirable (Table 1.

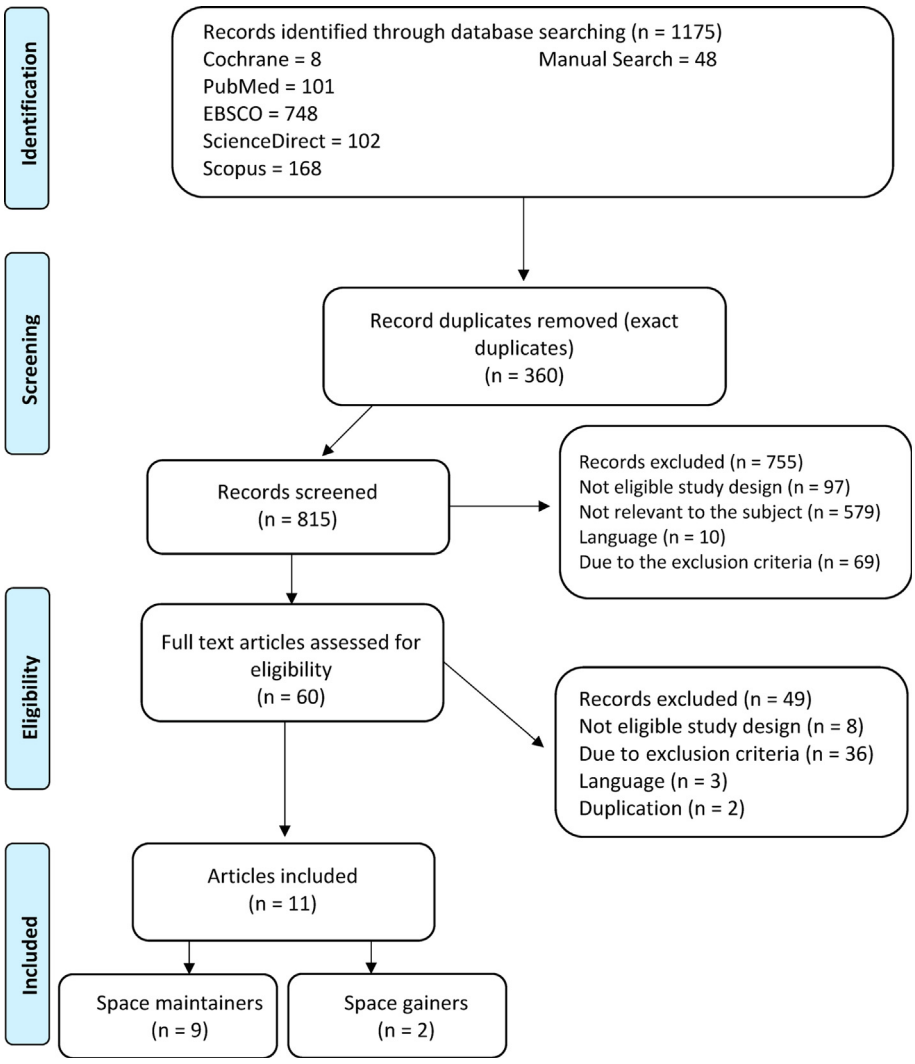

Fig. 1 Flow diagram of study identification and selection using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

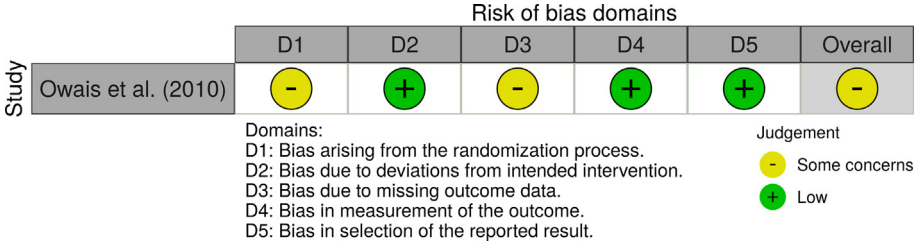

Fig. 2 Risk of Bias Assessment for the RCT included in this review.

3.3.2. Space regainers

Only two studies on space regainers met the inclusion criteria and were included in this systematic review (Nevant et al., 1991; Raucci et al., 2015). One study used a lip bumper and found that they were significantly effective in increasing the arch length (Nevant et al., 1991). Another study investigated the effect of transpalatal arch devices on increasing arch length in the maxilla (Raucci et al., 2015). They found that while transpalatal arch devices resulted in an increase in arch length, this difference was not significant, but the transpalatal arch was significantly effective in reducing dental crowding in the maxillary arch (Table 1.

3.4. Evaluating the certainty of evidence provided by this review

According to the GRADE system, the overall quality of evidence provided by this review was judged to be very low for both outcome measures, i.e., arch length and dental crowding,

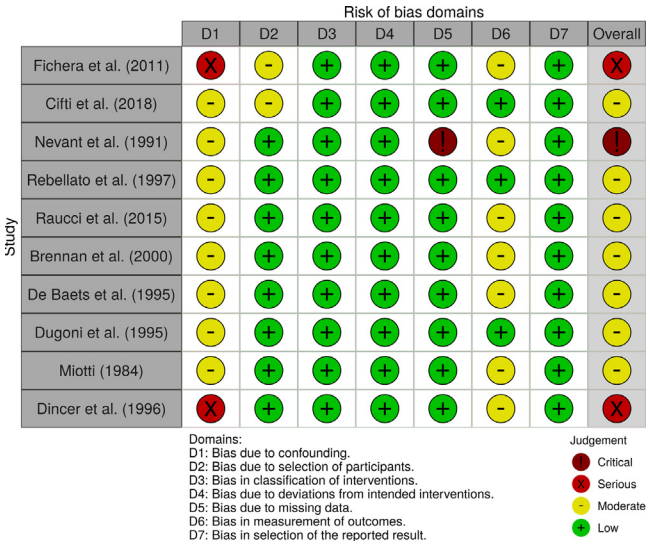

Fig. 3 Risk of Bias Assessment for the other studies included in this review.

due to the following factors: moderate to critical risk of bias across the included studies, small sample sizes investigated by the majority of studies, nonsignificant findings from a clinical point of view and conflicting findings reported by some included studies (Table 2).

4. 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 decreases in mixed dentition. Despite their common use, there is limited evidence about their effectiveness on arch length changes and potential crowding in the future (Owais et al., 2011).

4.1. 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 (Viglianisi, 2010; Chen et al., 2019). Therefore, the present review is the first study to assess the 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 an LLA on mandibular arch dimensions and showed that the LLA is effective in preventing a loss of arch length and tipping of the molars (Viglianisi, 2010). This result contrasts with the findings of 4 out of the 8 articles included in our review that reported a decrease in arch length following the placement of an LLA (Miotti, 1984; De Baets and Chiarini, 1995; Brennan and Gianelly, 2000; Ciftci et al., 2018). However, Viglianisi's review (2010) 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 LLA significantly increased intercanine and intermolar widths (Chen et al., 2019), a finding that is consistent with the findings of the present systematic review. Chen et al. also reported a nonsignificant increase in arch length and that LLA resolved mandibular incisor crowding and prevented incisors from tipping.

4.2. Effect of different space maintainers/regainers on total arch length

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 incisors, which may have contributed to preservation of the arch length. Other studies in our review also found that arch length would be preserved while using a lower lingual holding arch space maintainer (Fichera et al., 2011; Owais et al., 2011; Ciftci et al., 2018).

One study showed a decrease in the total arch length of 2.54 mm in the control group, who did not receive any kind of treatment. However, the treatment group, who only received a mandibular lingual arch appliance, had a slight increase of 0.07 mm (Rebellato et al., 1997).

On the other hand, Brennan et al. (2000) reported an average decrease in arch length by 0.44 mm 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%). They 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 LLA could have

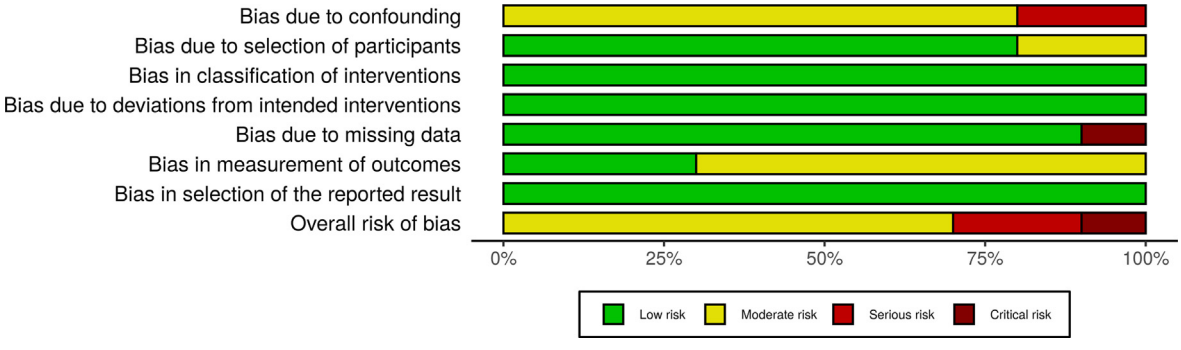

Fig. 4 Summary of the Percentage Allocation of Risk of Bias Grades in each Domain Across the 10 non-RCT studies.

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

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., 2011)	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 (< 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. ($P > 0.05$)
(Fichera et al., 2011)	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 ($P < 0.01$)
(Ciftci et al., 2018)	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. ($P > 0.05$)
(Nevant et al., 1991)	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. ($P < 0.05$)
(Rebellato et al., 1997)	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. ($P < 0.01$)

(*continued on next page*)

Table 1 (*continued*)

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)	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 approximately 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. ($P = 0.69$) Mean change of crowding in the treatment group: -4.3 ± 1.97 mm Mean change of crowding in the control group: 1.63 ± 2.45 mm Significant differences between the treatment and control groups and in the same group before and after treatment ($P < 0.0001$)
Brennan et al. (2000)	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 $0.44 \text{ mm} \pm 1.35$ mm. ($P < 0.01$) Average amount of incisor crowding resolved was 5.0 ± 2.1 mm and it decreased in 105 of the 107 patients.

Table 1 (*continued*)

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)	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. ($P > 0.05$)
(Dugoni et al., 1995)	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 $\geq$ 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). ($P > 0.05$)
(Miotti, 1984)	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. ($P > 0.05$)

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Table 1 (*continued*)

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
(Dincer et al., 1996)	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. Significant differences ($P < 0.001$) within the control group and between the groups

CEJ: Cementoenamel Junction.

unexpected results in the impact on arch length in certain patients.

De Baets et al. (1995) explained his reported decrease in arch length by movement of the labially inclined incisors to a more harmonious lingual position. In contrast, a study by (Dugoni et al., 1995) 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 mixed dentition but decreased during the postretention 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, 1984).

When comparing the use of lip bumpers and transpalatal arch appliances to regain spaces, it was found that the use of a lip bumper resulted in a significant regain of space compared to a nonsignificant regain of space from the latter. The reason for such a difference between the lip bumper and transpalatal arch was that the lip bumper utilizes the muscles of the lower lip to continuously apply a distalizing force on the mandibular first molars and allow the tongue to apply an opposed labial force on the mandibular incisors. Furthermore, it was found that a prefabricated lip bumper with a relatively thick shield extending from canine to canine had a mean annual increase of 7.45 mm/year in total arch length, while lip bumpers that were fabricated from 0.045 to inch stainless steel round wire resulted in an annual change of 2.66 m/year in the total arch length (Nevant et al., 1991; Raucci et al., 2015). The greater efficiency of a prefabricated lip bumper with a relatively thick shield is attributed to the greater contact areas with muscles of the lower lip, thus resulting in more distalizing forces of the lower lip.

The wide variation between the reported findings of the effectiveness of space maintainers and regainers may be attributed to different factors, such as variation in study design, e.g., self-control and untreated control, follow-up periods, and the time of placement of the space maintainers/regainers; their exact design, i.e., wire thickness, extension and number, dimensions and location of the incorporated loops; instructions to patients and maintenance; a wide variation of ages and genders of patients; and stages of dental development.

The majority of studies included in our review found a significant increase in intermolar, intercanine and interpremolar arch width after placing a space maintainer (Dugoni et al., 1995; Rebellato et al., 1997; Brennan and Gianelly, 2000; Owais et al., 2011; Raucci et al., 2015; Ciftci et al., 2018). 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;(Fichera et al., 2011; Owais et al., 2011) this explanation 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 (Dincer et al., 1996), while the increase in the intermolar width was most likely attributed to biological mechanisms (Ciftci et al., 2018).

4.3. 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%)

Table 2 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 [a]	Not serious [b]	Borderline serious [c]	Serious [d]	Not suspected [e]	Very Low ⊕○○○
Changes in crowding						
188	Serious	Not serious	Borderline serious	Serious	Not suspected	Very Low ⊕○○○

Explanations.

[a] Out of the 10 non-RCTs, one article was found to be of critical risk, two articles of serious risk and seven articles of moderate risk of bias. The RCT article was deemed to have 'some concerns' risk of bias.

[b] The majority of studies were similar in terms of the inclusion criteria of participants, interventions (lower lingual arch) and primary/secondary outcome measures (changes in arch length/changes in crowding).

[c] The total number of participants for the primary outcome measure was adequate (541). However, the included studies reported conflicting findings.

[d] Included studies reported different patterns and magnitudes of effect in the main/secondary outcome measures when comparing the intervention group with and a control group.

[e] A very comprehensive search of multiple sources was carried out, including the gray literature. Studies of positive and negative findings were published and included.

had a decrease in mandibular incisor crowding after LLA treatment (Dugoni et al., 1995; Brennan and Gianelly, 2000; Raucci et al., 2015).

Brennan and Gianelley (2000) 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., 1995) reported that early treatment with an LLA could result in better incisor stability in the postretention 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 regard to the effectiveness of the transpalatal 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 (Raucci et al., 2015). These results support the use of a space maintainer to prevent and decrease crowding in mixed dentition.

4.4. Clinical relevance and implications for future research

Overall, using a space maintainer may help reduce arch perimeter loss during the transition from mixed to permanent dentition (Rebellato et al., 1997). It seems that a lower lingual arch space maintainer made of a 0.9 mm diameter stainless steel archwire is associated with fewer problems than similar archwires but of a larger diameter (1.25 mm) (Owais et al., 2011). 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 (Ciftci et al., 2018). Moreover, it may be preferable to use prefabricated lip bumpers with thick acrylic sheets than other types, as the former have larger surface areas of plastic and thus have the potential to generate greater forces on the molars and bring about more distal movement (Nevant et al., 1991).

In view of very low evidence for effectiveness space maintainers and regainers, general dental practitioners should refer children with early loss of primary molars to an orthodontist to assess the case for the appropriate use of space maintainers or regainers to prevent future untoward consequences in such patients.

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

4.5. 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. The remaining 10 non-RCT studies were included in this review, and only half of them had 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. Moreover, studies included in this systematic review reported a wide variation of ages and stages of dental development, which may have different impacts on the effectiveness of the use of space maintainers/regainers. Furthermore, studies included in this review were dissimilar in terms of their designs, type of space maintainer/regainer, reported outcome measures, and follow-up periods, and none of them was deemed to have a low risk of bias. As a consequence, it was not possible to combine the findings of the included studies in a *meta*-analysis.

5. Conclusions

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

1. There is very low evidence to suggest that space maintainers/regainers using lower lingual arches, transpalatal arch devices and lip bumpers are effective in preserving arch length and preventing incisor crowding in patients during the mixed dentition stage.

2. High-quality well-designed studies are required to be able to form more definitive conclusions.

Funding

This study was not funded by any grant.

Ethical Statement

The systematic review was registered on the PROSPERO database (Registration number: CRD42020170035).

CRediT authorship contribution statement

Khaled Khalaf: Conceptualization, Methodology, Data curation, Validation, Formal analysis, Investigation, Writing – review & editing. **Aseel Mustafa:** Conceptualization, Data curation, Investigation, Writing – original draft. **Mohammad Wazzan:** Investigation, Validation, Writing – original draft. **Mennatalla Omar:** Investigation, Validation, Writing – original draft. **Mohammed Estaitia:** Investigation, Validation, Writing – original draft. **Mohamed El-Kishawi:** Validation, Investigation, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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