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REVIEW ARTICLE

Removable appliances to correct anterior crossbites in the mixed dentition: a systematic review

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ABSTRACT

Objectives: To investigate the effectiveness of an upper removable appliance in the treatment of an anterior crossbite in term of quality of life, effectiveness, treatment time, long term stability and cost minimization.
Design: Systematic review
Data source: A search strategy was implemented using both manual hand search and electronic databases, including Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, ScienceDirect, Scopus and Ebsco.
Study eligibility criteria: Randomized controlled clinical trials
Participants: Children in the early or late mixed dentition with an anterior crossbite affecting one or more incisors, and no underlying skeletal class III pattern.
Interventions: Upper removable appliance compared with other orthodontic appliances.
Study appraisal and synthesis: All potential articles were checked against the inclusion criteria independently, and in duplicate by two investigators. Risk of bias of eligible studies to be included in the final analysis was assessed independently by two authors using Cochrane risk of bias tool.
Results: A total of 524 articles were identified in both manual and electronic searches as well as by checking the reference lists of the final articles to be included in the study. Only 7 reports of 3 RCTs met the inclusion criteria and thus were included in the final analysis. All but one of the 3 RCTs were judged to be of very low quality. No statistical methods were employed to combine the studies due to the heterogeneity of the studies.
Conclusion: A fixed appliance was more cost-effective than a removable appliance in the correction of an anterior crossbite with a functional shift. There was no significant difference in terms of quality of life, pain intensity or long-term stability between the two appliances. On the other hand, both a removable appliance and cemented bite-pads were equally effective in the correction of an anterior dental crossbite without having any side effect.

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Anterior; dental crossbite; functional shift; mixed dentition; systematic review

Introduction

Rationale

An anterior crossbite is defined as an abnormal reversed labiolingual relationship of the incisors, where one or more primary or permanent maxillary incisors are located palatally to the mandibular incisors [1]. The prevalence of the anterior crossbite in the literature varies between 2.2% and 12% depending on the age of participants, ethnicity of the included subjects and the type of the anterior crossbite included in the data [2]. The anterior crossbite can be classified into: (1) An anterior dental crossbite caused by abnormal axial inclinations of the maxillary incisors resulting from trauma to a primary or permanent tooth bud, retained primary teeth, supernumerary teeth, an arch deficiency or an upper lip biting habit [3–5]. (2) A functional anterior crossbite due to the presence of premature occlusal contacts which in turn cause the mandible to shift anteriorly away from the normal path of closure and lead to what is called a pseudo-class III malocclusion [6]. (3) Skeletal anterior crossbite which is caused by a retrognathic maxilla, prognathic mandible or a combination of both due to genetic factors [7]. Furthermore, an anterior crossbite can lead to an adverse complication including gingival recession and mobility [8–10], TMJ disorders [11,12], as well as dental and facial disharmony [13–15]. Therefore, it's highly recommended to correct an anterior crossbite in the deciduous or early mixed dentition to allow a normal development of the occlusion and jaws. To date, several treatment modalities have been proposed to correct the anterior crossbite [16], but none was based on high-quality evidence. Therefore, the aim of this systematic review was to investigate the effectiveness of an upper removable appliance in the treatment of an anterior crossbite in term of quality of life,

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effectiveness, treatment time, long term stability and cost minimization.

Objectives

By summarizing the evidence from existing randomized clinical trials, this systematic review was designed to assess if there is a difference between an upper removable appliance and other treatment modalities in term of effectiveness, treatment time, long term stability, quality of life and cost-minimization in the treatment of both the anterior dental crossbite and the anterior crossbite with a functional shift.

Material and methods

In order to develop a well-structured design a PICOS methodology was used in this review as follows:

Population — children in their early to late mixed dentition with an anterior dental crossbite or anterior crossbite with a functional shift including at least one maxillary incisor involved in the crossbite with no previous orthodontic treatment or underlying skeletal class III pattern;
Intervention — an upper removable appliance;
Comparison — participants receiving treatment other than an upper removable appliance;
Outcome — correction of the dental crossbite or anterior crossbite with a functional shift in terms of quality of life, effectiveness, treatment time, long term stability and cost minimization;
Study design — RCTs.

Protocol and registration

The present systematic review was conducted using the Prisma checklist guidelines and registered in Prospero (International Prospective Register of Systematic Reviews) under the registration number CRD42018115937.

Information sources and search strategy

A comprehensive search strategy was implemented using both manual and electronic search methods in order to identify both indexed and non-indexed articles in databases as well as to reduce the possibility of excluding relevant studies by chance. The online database search strategy incorporated the following databases: Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, ScienceDirect, Scopus and Ebsco until November 2018 using the following keywords:

1. 'anterior crossbite' AND 'fixed appliance' OR 'removable appliance';
2. 'anterior crossbite' AND 'fixed appliance' OR 'removable appliance' AND mixed dentition;
   'anterior crossbite' OR 'anterior dental crossbite' OR 'anterior crossbite with functional shift' AND 'fixed appliance' OR 'removable appliance'.

The Manual hand search incorporated the following journals:

1. Journal of Orthodontics (2000–2018);
2. European Journal of Orthodontics (2000–2018);
3. American Journal of Orthodontic and Dentofacial Orthopedics (2000–2018);
4. Angle Orthodontist (2000–2018).

Before extracting data from eligible studies, a Cochrane data extraction form for RCTs was used in this systematic review. Data extracted from eligible studies included sample size, gender, number of dropped out participants, type of anterior crossbite, appliance used, quality of life, effectiveness, treatment time, long term stability and cost minimization at the end of the treatment. In case of any missing data or questions about the included papers, an attempt was made to contact the original study investigators. However, the potential implications for excluding any paper due to missing data will be discussed in the review.

Eligibility criteria

Articles were comprehensively examined against the inclusion and exclusion criteria and only studies involving (1) participants with an anterior dental crossbite or an anterior crossbite with a functional shift, (2) early to late mixed dentition, (3) at least one maxillary incisor involved in the crossbite and (4) no previous history of orthodontic treatment, were included in the systematic review. All papers that were not written in English, included participants with skeletal crossbite and participants in the permanent dentition were directly excluded. Abstracts, titles and subsequently full texts of potential articles were examined carefully and independently by two authors to make sure they were eligible to meet the inclusion criteria. Furthermore, references of all reviewed articles were examined to identify further articles for inclusion in the systematic review if they met the inclusion criteria.

Risk of bias and quality assessment in individual trials

All articles included in the study were reviewed independently by two authors in order to assess the level of bias using the Cochrane risk of bias tool which is an assessment tool that entails quality assessment based on five factors including selection bias (allocation concealment and methods of randomization), detection bias, performance bias, reporting bias and attrition bias [17]. Using the Grade approach (Grading of Recommendations Assessment, Development and Evaluation), the overall quality of evidence was assessed based on five factors: risk of bias, inconsistency, imprecision, indirectness and publication bias. The grade ratings of high, moderate, low, very-low quality evidence reflect how confident we are that the true effect lies close to the estimated effect in the systematic review [18].

Results

Study selection

The flowchart in Figure 1 identifies the included and excluded articles at each stage. Five hundred and twenty-four were assessed, including 520 articles from the electronic databases, 21 from the manual hand search and 2 articles from the reference lists. 19 articles were duplicates, and 377 did not relate to the research question, thus leaving 147 articles for potential inclusion in the study. Following the inspection of the full texts of these articles, 140 articles were excluded including 1 systematic review, 4 retrospective cohorts, 4 case series and 51 case reports. In addition, 80 articles were excluded for other reasons including papers involved participants with skeletal crossbites, participants in the permanent dentition or papers not written in English. This indicates that 7 studies were included. However, after contacting the studies investigators, 6 studies were reports of 2 RCTs. This means that 7 reports of 3 RCTs were included in the review for further analysis. The process of searching and selection of studies to be included in the review was carried out independently and in duplicate by the two authors and any disagreement was resolved through a discussion between them. The kappa statistic for the agreement between the reviewers was 0.87.

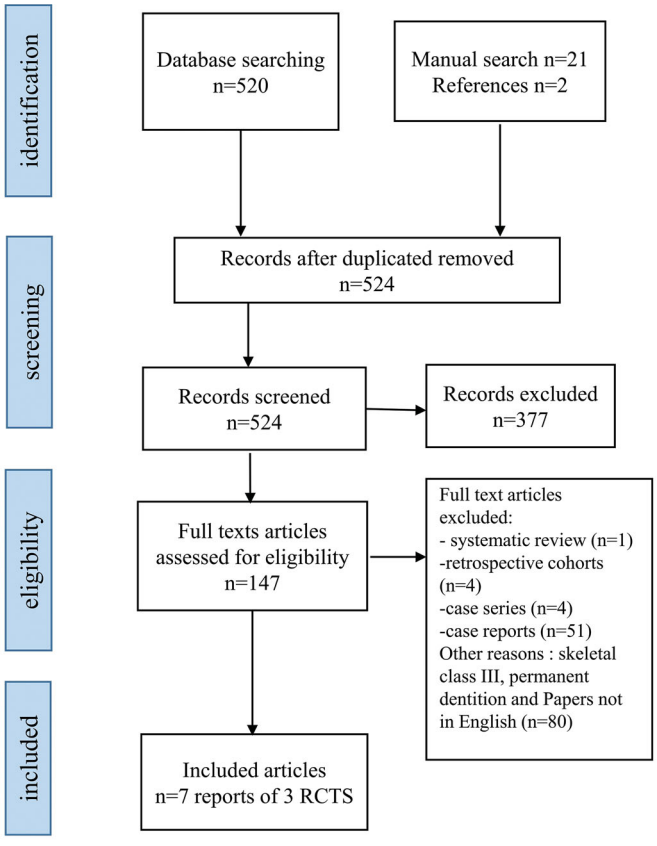

Figure 1. A flow chart describing the search methodology and numbers of articles included/excluded at each stage.

Risk of bias within studies

Using the Cochrane risk of bias tool, the quality of evidence of the Joyson 2018 study was assessed at high risk of bias. This is due to the absence of random sequence generation, allocation concealment and blinding of both participants and outcome assessors. On the other hand, the Wiedel RCT which is composed of 4 reports was assessed at unclear risk of bias. This is because blinding the participants and personnel was not possible. In addition to unclear risk of other biases including the difference in age between the intervention and the control group. Even though the randomization used in this study should have eliminated this type of bias. Furthermore, the Miamoto study 2018 was also assessed of unclear bias since blinding the participants was not possible as well as blinding the outcome assessors in one of the 2 reports was unclear (Figure 2).

Risk of bias across studies

According to the Grade system, the overall quality of evidence was observed to range between very low to moderate. One RCT was graded as of moderate quality due to unclear risk of bias which arises a doubt about the results of the study and causes a potential limitation that lowers the confidence in the estimate of effect. 2 RCTs were graded at very low quality due to imprecision (lack of sample size calculation and reporting of confidence interval), High risk of bias within the study or the presence of a bias other than the five factors (risk of bias, inconsistency, imprecision, indirectness and publication bias) which results in downgrading the quality of evidence (Table 1).

Results of individual studies

Removable versus fixed and functional appliance

The first randomized controlled trial estimated treatment duration and comfort equation of three different appliances including fixed, removable and functional appliances to correct a developing single tooth crossbite. The treatment duration to correct the anterior crossbite by a fixed appliance was found to be 11 days, by a functional appliance was 21 days and by a removable appliance was 15 days. In addition, comfort equation (communication, mastication, oral hygiene, pain and discomfort) was better in the fixed appliance group. Unfortunately, this article had unclear method of random sequence generation, and unclear blinding and allocation concealment [19].

Removable appliance versus cemented bite-pads

The second and third studies were reports of one RCT [20,21]. The sample of this study consisted of 30 participants 8–10 years old with an anterior dental crossbite in the mixed dentition and no previous history of orthodontic treatment. All first permanent molars erupted with at least one permanent incisor in crossbite. The participants were divided into two groups each of 15 participants. The first group received an upper removable appliance with two Adams clasps on the first permanent molars, two arrow clasps between the deciduous molars, a double finger spring applied to the teeth in a crossbite, a labial bow and an occlusal splint in

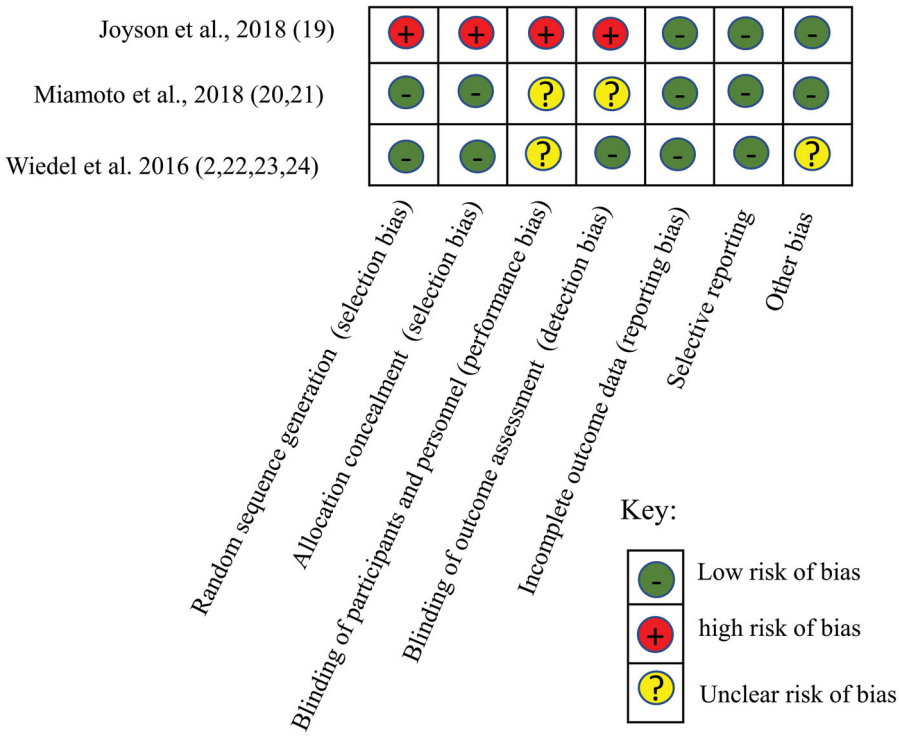

Figure 2. Quality assessment of the studies included in the systematic review using 'Cochrane risk of bias' tool.

Table 1. A summary of GRADE's approach to rate the overall quality of evidence.

Article	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall quality of evidence
Joyson et al. [19]	Very serious	Not serious	Not serious	Serious	None	Very low ⊕○○○
Miamoto et al. [20,21]	serious	Not serious	Not serious	Not serious	None	Moderate ⊕⊕⊕○
Wiedel et al. [2,22,23,24]	serious	Not serious	Not serious	serious	None	Very low(1) ⊕○○○

(1)Downgraded due to the difference in age between the control and the intervention group.

the posterior region to open the bite and allows the teeth in crossbite to move freely under the force application. The second group received resin-reinforced glass ionomer bite-pads on the occlusal surfaces of the mandibular first permanent molars to disocclude the anterior teeth and allow them to be corrected under the tongue pressure. After 12 months of treatment, both groups had an increase in the overjet, mandibular intercanine width, maxillary intercanine width and an upper incisor inclination with no significant differences between the two groups. Using the Brazilian version of the Child Perception Questionnaire (CPQ) the second report of this study assessed the overall oral health-related quality of life including oral symptoms, functional limitations, emotional well-being and social well-being at the beginning of treatment and 12 months after treatment. It was found that at the end of treatment the quality of life of children who had undergone treatment with an upper removable appliance improved while children who had received resin reinforced bite-pads had no improvement in their quality of life outcome, but there was no statistical difference in the quality of life between the two groups.

Removable versus fixed appliance

The remaining 4 papers included in this systematic review were reports of one RCT [2,22–24] to investigate different outcomes concerning the effectiveness of a removable appliance VS a fixed appliance in the correction of an anterior crossbite with a functional shift. Sixty-one participants who were in their late mixed dentition, had an anterior crossbite with a functional shift, non-extraction treatment plan, a moderate space deficiency in the maxilla and no previous history of orthodontic treatment were divided into two equal groups of 32 participants each. The first group received a removable appliance with an expansion screw and a protrusion spring adapted to each incisor in crossbite. Furthermore, the appliance incorporated bilateral occlusal coverage of the posterior teeth and clasps on the first deciduous molars or on the first premolars in case they were erupted and on the first permanent molars. Lateral occlusal coverage was used to allow the incisor in crossbite to move without vertical interlocking with the mandibular incisors as well as to add more retention to the appliance. The second group received fixed appliance therapy with stainless steel brackets (Victory, slot 0.022, 3 M Unitek, USA). Brackets were bonded to the deciduous canines, maxillary incisors, and to the first deciduous molars or to the first premolars (if erupted). All participants who received fixed appliance therapy were treated according to a standard straight-wire concept designed for light forces. The arch wire sequence was 0.016 heat-activated nickel–titanium (HANT), 0.019×0.025 HANT, and 0.019×0.025 stainless steel arch wire. Composites were bonded to the occlusal surfaces to open

the bite and allow the teeth in crossbite to move under the force application. At the end of treatment, the average treatment time of participants in the fixed appliance group, including a 3 months retention period, was significantly less (5.5 months) compared to that in the removable appliance group (6.9 months). Moreover, the increase in the overjet after treatment and arch length measurements [arch length to incisal edge (ALI) and arch length gingival (ALG)] were significantly greater in the fixed appliance group than in the removable appliance group. Both groups had a low to moderate pain intensity, and both appliances were generally well tolerated by the participants. However, the fixed appliance group showed more pain in the first 2 days. After 4 to 8 weeks of treatment no significant difference was found between the two groups regarding quality of life. In addition, after 2 years of follow up both appliances showed similar stabilities with a favourable prognosis. Furthermore, comparing the direct costs (staff salaries, premises, material, and laboratory costs) and indirect costs (loss of income due to parents' absence of work) between the fixed and removable appliance groups showed that a fixed appliance was more cost-effective in treating the anterior crossbite with a functional shift than a removable appliance (Table 2).

Discussion

Summary of main results

The results of this study reject the null hypothesis that there is no difference between cemented bite pads and fixed appliance against the upper removable appliance in term of effectiveness, treatment time, long term stability, quality of life and cost-Minimization to correct the anterior dental crossbite and the anterior crossbite with a functional shift.

Removable appliance versus cemented bite-pads

To date, the existing literature lacks high-quality evidence regarding the best treatment modality of an anterior crossbite. It was found from the current systematic review that an upper removable appliance with a finger spring and cemented bite-pads which uses the tongue pressure to move the teeth in a crossbite, though the latter are not commonly used, were both equally effective in the correction of an anterior dental crossbite affecting one or more incisors. This may be explained by the fact that both appliances share a similar mechanism of action which is based on discluding the anterior teeth in crossbite to allow them to move freely over the bite following a force application by either a spring or by tongue pressure. The implication of this finding in our clinical practice is that in a patient who cannot tolerate the wear of a removable appliance or is not co-operative in the wear of the removable appliance, occlusal bite-pads may be used to effectively correct the crossbite. Furthermore, a patient with inadequate oral hygiene or a patient who is prone to a removable appliance-induced stomatitis can be a good candidate for the application of occlusal bite pads to correct their anterior crossbites without iatrogenic effects.

Also, it was found that the quality of life of participants treated with an upper removable appliance had improved at the end of their treatment, whereas there was no improvement noticed in the quality of life of participants that had received cemented bite pads. However, the differences found in the quality of life between the two groups were not statistically significant. This may be explained by the simple design and similar mechanism of action of both treatment modalities which make their impacts on the quality of life to be similar.

Removable versus fixed appliance

When comparing the removable with the fixed appliance in the correction of an anterior crossbite with a functional shift the average duration of treatment time in the fixed appliance group was 5.5 months compared to 6.9 months in the removable appliance group. Thus, the fixed appliance saved 20% of the total treatment time. The longer treatment time in the removable appliance group may be due to the lack of patient's compliance with the appliance wear [25], which is an essential element in the treatment protocol with a removable appliance. However, it can be argued that a difference of 1.4 months, which equates to 6 weeks period in treatment duration, between the two appliances is not clinically significant as it will add only a one to two follow-up visits by the patient. In addition, it was found that a fixed appliance was more cost-effective than a removable appliance in the correction of a crossbite when both direct and indirect costs where compared. This may be attributed to the longer treatment time in the removable appliance group which in turn requires one or 2 more appointments and to the laboratory cost of constructing the removable appliance. These findings are in accordance with a previous study which analyzed the cost-effectiveness between a quad-helix appliance and an expansion plate in the treatment of a unilateral posterior crossbite in the mixed dentition [26].

The pain level for both the removable and fixed appliance groups was found to range between low to moderate. However, pain intensity in the fixed appliance group was significantly greater in the first 2 days of treatment, but thereafter both groups had the same level of pain intensity. These findings are in agreement with Erdinç and his co-worker's study which concluded that pain intensity in participants receiving fixed appliance therapy started to decline by day 3 [27]. The difference in pain intensity between the two appliances especially in the first 2–3 days may most probably be ascribed to the greater forces delivered by the fixed appliance as compared to those delivered by the removable appliance [28]. In addition, when using a fixed appliance, the forces applied to the teeth in crossbite are disseminated to the remaining teeth in the dental arch as opposed to the remaining teeth and palate in a patient who is treated by a removable appliance. On the contrary, one study found that a fixed appliance produced more discomfort and pain than a removable appliance throughout the treatment course [29]. However, that study was a retrospective cohort study with several biases and confounding variables including but not

Table 2. Removable appliance VS other treatments in the correction of an anterior dental crossbite and an anterior crossbite with a functional shift.

Study	Participants sample size, gender, age (years), dropout	Anterior crossbite	Intervention	Effectiveness	Cost minimization	Quality of life(QoL)	follow up/ stability
Joyson et al. [19]	$N = 30$ participants (17 girls, 13 boys) Mean age = 8 No dropout	Anterior dental crossbite	URA (Hawley appliance with a double cantilever spring) VS Catlan's appliance VS fixed appliance	Fixed appliance group had the shortest treatment time (11 days) followed by the URA group (15 days) and Catlan's appliance group (21 days). URA VS Fixed appliance mean difference = 4 days. URA VS Catlan's appliance mean difference = 6 days	Not measured	Quality of life was better in FA group followed by URA and Catlan's appliance	No follow up
Miamoto et al. [20,21]	$N = 30$ children (18 boys/12 girls) Age range = 8–10 No dropout	Anterior dental crossbite	URA with a finger spring VS bite-pads cemented	Over the same period of time (12 months) no significant difference was observed between the two treatments. Mean difference of overjet between the groups is (0.40) Overjet: CI (95%) [−0.33–1.07] p=.326	Not measured	No significant difference between the two treatment protocols	12 months of follow up with no side effects
Wiedel et al. [2,22,23,24]	$N = 62$ participants (25 girls, 37 boys) Mean age = 9.75 1 patient dropped out	Anterior crossbite with a functional shift	URA with Z-spring and an expansion screw VS fixed appliance	Fixed appliance group had a shorter treatment time (5.5 months) compared to the removable appliance group (6.9 months). With a 1.4 month Mean difference in treatment time. (p<.05) The increase in overjet (p<.05), ALI (p<.01) and ALG (p<.001) between groups were significantly greater in the fixed appliance group than in the URA group	both indirect costs (mean difference is 81) and direct costs for material (mean difference is 202) were statistically significant between the two groups and less in the fixed appliance group. Direct cost-material: 95% (166–225) p=.000 indirect cost: 95% (19–124) p=.006	Both appliances produced low to moderate pain intensity with minor clinical significant differences on day 2 (p=.017) between both groups	After 2 years post retention follow up, 2 cases relapsed in the fixed appliance group VS 1 case in the removable appliance group. Both appliances showed equal stability and favorable prognosis

limited to the lack of reporting of the type of malocclusion of participants treated by both appliances.

Furthermore, it was found in the current systematic review that participants who received the treatment by a removable appliance experienced more pain in the palate and had more speech difficulties, whereas participants in the fixed appliance group experienced more pain when eating hard and soft foods. This is most probably due to the differences in the appliance design, force dissemination and anchorage reinforcement between the fixed and removable appliances.

At 2 years post-retention follow up participants treated by each appliance showed a stable result and favourable prognosis. This finding is expected as the relapse of orthodontic tooth movement is related to the severity of the initial malocclusion and not to the method of applying the orthodontic forces. As the participants in the RCT included in this systematic review were randomly allocated to the removable and fixed appliance groups it is expected for the participants in both groups to have the same initial malocclusion and thus similar relapse potential in the long-term.

Agreements and disagreements with other studies or reviews

To our knowledge, this is the first systematic review to directly compare between removable appliance and other treatment modalities to correct the anterior dental crossbite and the anterior crossbite with a functional shift in the mixed dentition. Therefore, a comparison with previous studies can't be made. While not directly comparable, a Cochrane systematic review was conducted in 2013 by Watkinson et al. to assess the effect of orthodontic treatment with a facemask to correct prominent lower anterior teeth (class III malocclusion) emphasized that the use of a facemask to correct this type of malocclusion in children is effective when compared to no treatment on a short-term basis [7].

Potential biases in the review process

Every attempt was made to limit the risk of bias in the review process starting from conducting a comprehensive and independent electronic and manual hand search strategy to reduce the possibility of excluding relevant papers by chance, including only randomized clinical trials which is considered to be less biased when compared to other study designs when conducted to a high standards, independent assessment of risk of bias within the included studies by the two authors and contacting the original study investigators to obtain clarification about certain unclear details in the reports. when these methods were applied it was stated explicitly by the authors in the text of this review.

Conclusions

- Both upper removable appliance and cemented bite pads are effective in the treatment of an anterior dental crossbite without having any side effects over a follow-up period of 12 months.
- In the correction of an anterior crossbite with a functional shift a fixed appliance is more cost-effective and has the capability to reduce the treatment time by up to 20% when compared to a removable appliance.
- There was no significant difference in term of quality of life, pain intensity or long-term stability between the two appliances.
- Based on the limited number of high quality of the included studies in this systematic review the above conclusions should be interpreted with caution, and well-designed RCTs are needed.
- This systematic review conforms to the PRISMA statement [30]. A 2009 PRISMA checklist is provided as a supplementary document.

Disclosure statement

No potential conflict of interest was reported by the authors.

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