

REVIEW

2 × 4 appliance in the mixed dentition stage: a scoping review of the evidence

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Abstract

A great emphasis is currently given to the early correction of malocclusions to prevent further complications if left untreated. Interceptive orthodontics not only simplifies but also eliminates the need for later procedures. The 2 × 4 appliance is an orthodontic treatment modality applied during the mixed dentition period, particularly for malpositioned permanent upper incisors. This scoping review was aimed to examine the breadth and depth of the published literature on this clinical topic, as well as knowledge gaps, about this fixed appliance during mixed dentition, for the correction of incipient anterior malocclusions (incisor crowdings, midline diastemas, or crossbites). PubMed, Cochrane Library, Google Scholar, Dentistry & Oral Sciences Source, and two grey literature databases were explored; under a structured PICO question (Patient, Intervention, Comparison, Outcome) and eligibility criteria, for relevant clinical trials, observational studies, and case reports/series (in English or Spanish), using different searching terms. Titles and abstracts were screened. Full-text articles were critically reviewed for bias risk and a data charting table was constructed. 161 references were identified, after which 115 titles remained after removing duplicates. After the abstract screening, 18 potential full-text articles were reviewed. Finally, 16 studies were included, according to the performed critical appraisal. The 2 × 4 appliance is suitable for mixed dentition patients with mild or severe malocclusions, particularly when removable appliance usage is a critical problem.

Keywords

2 × 4 appliance; Early orthodontic treatment; Mixed dentition

1. Introduction

Preventive and interceptive orthodontics treatments are carried out during the primary and mixed dentitions to resolve or alleviate diverse early occlusal abnormalities in children and to allow normal skeletal pattern development for the next years [1]. Although this statement has been the cause of debate for many years, some authors establish that the opportune application of orthodontic therapies (6 to 8 years old) has the potential to capture a longer period of near-peak growth [2–4]. Even though orthodontics with fixed appliances for definitive dentoalveolar corrections is usually deferred until well-established permanent dentition, diverse limited orthodontic strategies may be implemented to prevent and/or reduce the abnormal progression of local malocclusal traits during the mixed dentition [5–7]. Early orthodontics has the purpose of resolving dentoalveolar irregularities, functional interferences, and skeletal and muscular imbalances, to improve the orofacial environment before the complete eruption of the permanent teeth; and thus, simplify or eliminate the need for later orthodontic treatment [3, 8, 9].

The 2 × 4 appliance (alone or with other fixed devices)

is considered a very versatile, comfortable, easy-to-use, and well-tolerated appliance [4, 6]. This fixed appliance represents an orthodontic treatment modality applied during the early mixed dentition period, particularly for malpositioned permanent upper incisors, in order to harmonize the occlusion [10]. The appliance's basic design comprises the placement of bands with soldered stainless-steel tubes (to support the archwire) on the first permanent molars, bonded brackets on the erupted incisors, and light wire continuous arches [11]. The 2 × 4 technique provides effective control over the anterior dentition-tooth movement (force magnitude and vector) in all three dimensions (bodily or translational movements, tipping, torque of roots, and rotations)-and to maintain the adequate arch shape [1, 4].

The appliance allows a fast and more predictable outcome, in a single short phase, for complex occlusal disorders such as anterior/posterior crossbites, ectopic or impacted upper permanent central incisors, incipient anterior crowding with misaligned teeth (mild rotations, midline diastemas, abnormal spacing, improper axial inclinations or angulations), and other minor malocclusal disorders during the mixed dentition [6, 12–17]; these malocclusions involve a single tooth or a set of

teeth in the arch [11]. The clinician must consider that a 2×4 appliance is not necessarily the definitive course of the orthodontic treatment, and the patient should be warned of this [6].

During the mixed dentition stage, interceptive management of malocclusions, particularly those located in the anterior segments of both arches, represents a suitable approach that provides rapid clinical effectiveness and psychological benefit for the child. For this purpose, pediatric dentists can offer the 2×4 appliance to their young patients, as an alternative orthodontic treatment that is easily placed and removed, inexpensive, comfortable, and well tolerated, requiring only minimal child's cooperation. In this context, this scoping review aimed to identify and evaluate the most relevant published studies in the last 20 years and perform a critical reflection on the 2×4 appliance applied during the mixed dentition stage, for the correction of incipient anterior malocclusions (such as incisor crowdings, midline diastemas, or crossbites). Due to the scarcity of available dental literature related to this clinical topic, the present scoping review intends to provide an overview of the existing content, establishing both conclusions and tendencies for future research.

2. Methods

2.1 Design

The present scoping review was designed and developed following the methodology stated by Arksey & O'Malley [18], Levac and co-workers [19], and the Preferred Reporting Item for Systematic Reviews and Meta-analysis extension for scoping reviews guidelines (PRISMA-ScR) [20]. A 'scoping' study encompasses a further type of literature review, whose main purpose is to map relevant literature and the key concepts underpinning a clinical topic of interest. Furthermore, the main sources and types of evidence available, especially when this topic has not been reviewed comprehensively before. In general, a scoping review consists of five steps: (i) constructing the research question, (ii) identifying relevant studies, (iii) study selection, (iv) charting the data, and (v) collating, summarizing, and reporting the results. Nowadays, scoping reviews represent an increasingly popular approach to reviewing dental research evidence. Scoping studies differ from systematic reviews because authors do not assess the quality of included studies; scoping studies also differ from narrative or literature reviews in that the scoping process requires analytical reinterpretation of the literature [19].

The present scoping review was conducted following the Preferred Reporting Items for Scoping Reviews 2020 methodology guidelines (<https://prisma-statement.org/Extensions/ScopingReviews>). The study protocol was approved *a priori* by all authors and later registered in the Open Science Framework (OSF) database, under the Registration DOI 10.17605/OSF.IO/BWK8N.

2.2 Question research

A scoping review intended to answer the following PICO (population, intervention, comparison, outcome) question research: In pediatric patients at mixed dentition stage (P), what are

the early clinical benefits of using the 2×4 appliance (I), in comparison with other orthodontic appliances (C), in the correction of diverse common malocclusions at this age (O)?

2.3 Eligibility criteria

References from publications focused on the 2×4 appliance, in which the authors explored and described the different clinical and technical procedures for the resolution of different malocclusions in the mixed dentition stage were screened. Inclusion criteria: only available (1) randomized controlled clinical trials, (2) observational studies (e.g., cohort, case-control, cross-sectional designs), (3) pilot studies, and (4) clinical case reports/series were eligible. These articles should have been written in English languages only and published between 2000 and 2022. The reasons why the authors limited the inclusion of only English studies were the restricted language skills for other languages translation (except for Spanish articles). Exclusion criteria: studies performed in permanent dentition (adolescents or adults; e.g., treatment of ectopic or impacted upper permanent canines), narrative reviews, and letters to the editor were excluded. Reasons for exclusion after full-text reading were recorded.

2.4 Study screening selection

A structured electronic and manual search was conducted on four electronic databases: PubMed, Cochrane Library, Google Scholar, and Dentistry & Oral Sciences Source (EBSCO); two grey literature databases were also consulted (GreyNet and Grey Literature Report). The following MeSH or free-text terms, keywords, and Boolean operators were used, alone or in combination: "early orthodontic treatment", "interceptive orthodontics", "mixed dentition", "fixed orthodontic appliances", and " 2×4 appliance". This search strategy was appropriately adapted for each database. In PubMed, the next search algorithm was employed:

((("early" (All Fields) AND ("orthodontal" (All Fields) OR "orthodontic" (All Fields) OR "orthodontical" (All Fields) OR "orthodontically" (All Fields) OR "orthodontics" (MeSH Terms) OR "orthodontics" (All Fields)) AND ("therapeutics" (MeSH Terms) OR "therapeutics" (All Fields) OR "treatments" (All Fields) OR "therapy" (MeSH Subheading) OR "therapy" (All Fields) OR "treatment" (All Fields) OR "treatment s" (All Fields))) OR ("orthodontics, interceptive" (MeSH Terms) OR ("orthodontics" (All Fields) AND "interceptive" (All Fields)) OR "interceptive orthodontics" (All Fields) OR ("interceptive" (All Fields) AND "orthodontics" (All Fields)))) AND ((("2 x 4" (All Fields) AND ("appliance" (All Fields) OR "appliances" (All Fields) OR "instrumentation" (MeSH Subheading) OR "instrumentation" (All Fields) OR "appliances" (All Fields)) OR ("two" (All Fields) AND "four" (All Fields) AND ("appliance" (All Fields) OR "appliances" (All Fields) OR "instrumentation" (MeSH Subheading) OR "instrumentation" (All Fields) OR "appliances" (All Fields))))

Titles and abstracts derived from the electronic and hand searches were carefully reviewed and screened by two independent, trained, and pre-calibrated authors (GHG and EYG), according to the inclusion and exclusion criteria, for selecting

the most relevant records. Any title/abstract classified as potentially eligible or relevant by either reviewer was retrieved in full text and independently evaluated. The reference lists of the reviewed articles were also hand-searched for additional studies that may have been missed in the initial search. In cases in which significant data were missing from the article, the reviewers made an effort to contact the authors to obtain this extra information. The levels of inter- and intra-reviewer of these authors were determined using Cohen's kappa coefficient [21]. Any discrepancy or conflict of opinion was resolved through discussion and consensus by consulting the other two authors (SRR and MRB).

2.5 Data charting and result synthesis

A predesigned/standardized tabular form for data charting was constructed and piloted with relevant information entries, and approved by all authors' consensus. From each selected article, the following items were summarized and recorded: publication first author and year, country, study methodological design, clinical interventions and related outcomes, and main findings. In cases of observational (cross-sectional or longitudinal) studies, target population, sample size, and follow-up period (*e.g.*, cohort designs) were also taken. All items were collected by two experienced reviewers (SRR and MRB) independently; again, any disagreement or discrepancy was resolved by discussion and consensus with the other authors.

2.6 Bias risk

The methodological quality of included randomized controlled clinical trials was evaluated through the Cochrane tool, which is based on random sequence generation, allocation concealment, blinding of participants/evaluators, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias [22]. The bias risk of observational studies was assessed through the Newcastle-Ottawa tool based on selection, comparability, and exposure [23]. For clinical case reports/case series, the tool developed by Murad *et al.* [24] was employed. Only those studies with moderate to high quality were included in the final list of the present scoping review.

3. Results

3.1 Study selection

A total of 161 references were identified in the different electronic databases, after which 115 titles remained after removing duplicates. After the article title and abstract screening, 18 potential full-text articles were carefully reviewed. Finally, 16 relevant and most informative studies, according to the performed critical appraisal, were included in the present scoping review. Even though articles written in a language other than English were not eligible, one relevant article written in Spanish was retrieved and finally included. The whole selection process was according to the PRISMA-ScR statement flowchart, as can be seen in Fig. 1. On the other hand, good to very good intra- and inter-reviewer agreement levels were found for the search strategy and screening processes, accord-

ing to the kappa coefficients (0.87 and 0.91, respectively).

Regarding the study methodology, fourteen studies were case reports/case series with a brief narrative review and clinical treatment descriptions, and two were randomized controlled clinical trials; no descriptive or comparative cross-sectional designs, case-control studies, or cohorts were detected. Regarding the authors' country, most articles were conducted in India and Europe (mainly in the UK). Two studies presented any type of descriptive or inferential statistical analysis (with *p* values). The publication dates ranged from 2000 to 2020. The main characteristics, numerical data, findings, and conclusions from these articles were summarized in a **Supplementary Table 1** [1, 4, 9, 10, 12–17, 25–30].

3.2 Critical review

Qualitative analysis of case reports/case series and risk of bias assessment of clinical trials are depicted in Tables 1 [1, 4, 9, 10, 12–17, 26, 28–30] and 2 [25, 27], respectively.

4. Discussion

Based on the results of the exhaustive search process for recent and relevant published evidence on the 2×4 appliance during mixed dentition, it can be shown that few randomized clinical trials or quality longitudinal observational studies about this clinical topic have been published in the last recent years. Most of the selected articles here were clinical case reports that, although well written, represent a low-quality level among the different methodological designs used in dental clinical research; this can be an inconvenience for the current scoping review.

Malocclusions can be detected at any stage of the dentition and do not self-correct; so, they must be treated as soon as possible [10, 30]. Mixed dentition is a period in which occurs rapid growth and development of the craniofacial skeleton. Several types of malocclusions can be successfully managed during this stage because hard tissues are highly responsive to orthodontic forces, and soft tissues exhibit a greater degree of adaptability, thereby increasing the stability of treatment results; it also may ensure the normal development of teeth and jaws [31].

A variety of potential benefits from early fixed orthodontic treatment in mixed dentition has been proposed in the dental literature [1, 4, 16, 31, 32]: (i) better access to enhanced oral hygiene; (ii) patient's enhanced esthetic appearance, psychosocial development, and self-perception/esteem, reducing thus teasing and bullying; (iii) increased orofacial growth response; (iv) greater ability for orofacial growth modification, for example, when aberrant oral habits (*e.g.*, thumb sucking) are opportunely approached; (v) cost-effective; (vi) stability: less need of orthodontic treatment is required later; (vii) minimal root resorption; and (viii) reduced risk of damage because of dentofacial trauma. Besides, 2×4 appliances do not require any adjustment by the patient or parents [14]. Also, this appliance can be modified, *e.g.*, wire loops can be added for the support of inter or intra maxillary elastics (especially useful for the traction of ectopic or impacted permanent upper canines, at later ages), or open-coil springs for the creation of space in the

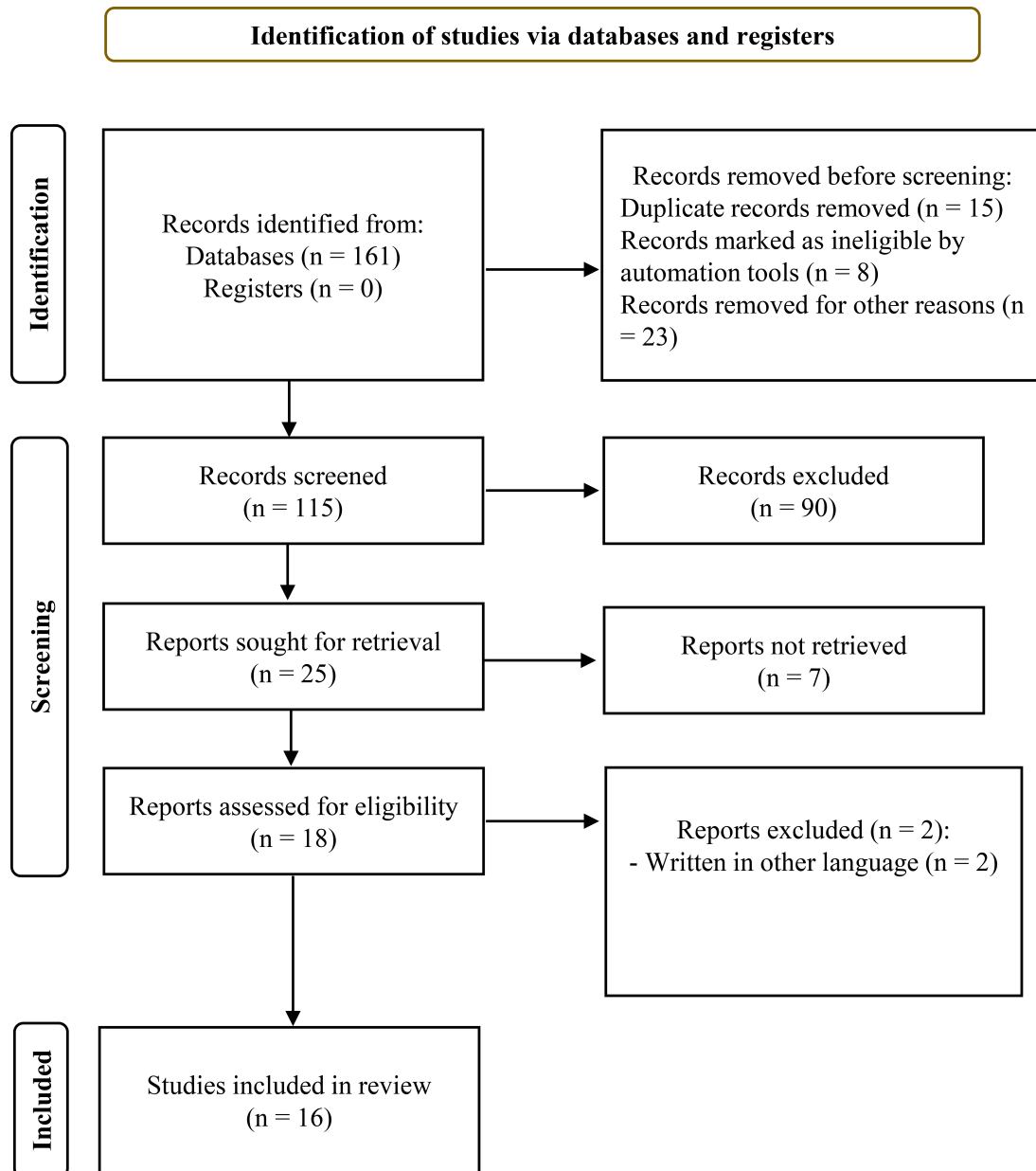


FIGURE 1. Flow chart for literature search.

dental arch.

So, 2×4 orthodontic therapy is very popular among general dentists, pediatric dentistry practitioners, and orthodontists. In a survey conducted by Quinzi and colleagues [33] on a sample of 200 Italian dentists, it was concluded that 93.94% of orthodontists and 51.49% of general dentists have knowledge of the appliance and routinely use the technique in their clinical practice. Conversely, the main disadvantages of the device are [11, 15]: (i) the patient may need a second phase of orthodontic treatment in the future; (ii) placement of bands can be difficult in not fully erupted permanent molars, which can cause discomfort in the child and the possible refusing of further treatment; (iii) limited anchorage; (iv) the distally extended archwire behind the molars tubes can be dislodged during eating or brushing; (v) the technique cannot correct skeletal malocclusions or abnormal intermaxillary relationships (mesio/disto malocclusions); (vi) the technique is unable to modify inadequate oral muscle patterns, unlike orthopedic

removable appliances; and (vii) it is unsuitable for primary dentition.

In this regard, only a few of the malocclusions present in the mixed dentition stage can be treated using removable appliances [4]. These devices lack control over tooth position, and the fact that they can exert the force at a single point on the tooth's surface, they only provide coronal tipping movements; thus, no bodily displacements are possible [27]. Even though etching, bonding, and debonding procedures are avoided, removable appliances require comprehensive compliance by the patient to be worn and cleaned [1]. Children often have the propensity to flick the appliances in and out with the tongue or fingers, which can lead to stress and fracture of the retention cribs and clasps, and later, to the progressive loosening of the appliance; breakage, and loss of devices due to child's carelessness are also frequent [4, 14, 15]. These reasons prevent guaranteeing the success of the treatment [28]. On the other hand, the 2×4 appliance can be carried out at a

TABLE 1. Qualitative assessment of case reports/case series [24].

Author, year	Does the patient(s) represent(s) the whole experience of the investigators?	Was the exposure (treatment) adequately ascertained?	Was the outcome(s) adequately ascertained?	Were other alternative causes that may explain the observation ruled out?	Was there a challenge /rechallenge or phenomenon?	Was follow-up long enough for outcomes to occur?	Is the case(s) described with sufficient details to allow replications or inferences?
Fiona, 2001 [12]	Yes	Yes	Yes	No	No	Yes	Yes
Dowsing, 2004 [13]	Yes	Yes	Yes	Yes	No	Yes	Yes
da Silva Filho, 2006 [10]	Yes	Yes	Yes	No	No	Yes	Yes
Agarwal, 2011 [26]	Yes	Yes	Yes	Yes	No	Yes	Yes
Singhal, 2015 [14]	Yes	Yes	Yes	Yes	No	Yes	Yes
Yordanova, 2016 [28]	Yes	Yes	Yes	No	No	Yes	Yes
Harika, 2016 [29]	Yes	Yes	Yes	Yes	No	Yes	Yes
Sunil, 2017 [30]	Yes	Yes	Yes	Yes	No	Yes	Yes
Rohilla, 2017 [1]	Yes	Yes	Yes	No	No	Yes	Yes
Solanki, 2017 [4]	Yes	Yes	Yes	Yes	No	Yes	Yes
Nagarajan, 2018 [15]	Yes	Yes	Yes	Yes	No	Yes	Yes
Soni, 2019 [9]	Yes	Yes	Yes	No	No	Yes	Yes
Das, 2020 [17]	Yes	Yes	Yes	No	No	Yes	Yes
Kumari, 2020 [16]	Yes	Yes	Yes	Yes	No	Yes	Yes

TABLE 2. Bias risk evaluation in selected clinical controlled trials [23].

Author, year	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other sources of bias
Gu, 2000 [25]	No	No	No	No	No	No	No
Wiedel, 2015 [27]	Yes	Yes	No	Yes	No	No	No

single visit but requires more chair-side time to fit (including enamel etching and bracket bonding); no laboratory facilities are involved [1, 9, 26]. Besides, the child's normal speech is not affected [28].

In the next section, we will summarize the collected information about the principal applications and diverse clinical considerations of the 2×4 in pediatric patients at the mixed dentition stage:

4.1 Anterior and posterior crossbites

Anterior crossbite is usually a major functional and esthetic issue during the early stages of oral development in children [9]. There is an old orthodontic maxim: “the best time to treat a crossbite is the first time it is seen” [30, 34]. Early management of anterior crossbites has been strongly recommended for avoiding the possible progress of the condition to a true class III malocclusion in the future [27, 28]. The 2×4 appliance is frequently employed for the correction of crossbites in the mixed dentition because it allows the protrusion of upper incisors and the stimulation of bone development in the root apex area [28]. It is mandatory the previous elimination of those premature contacts between opposite teeth, in cases of functional crossbites [9, 15].

The appliance has a great power of action and can provide lighter continuous forces for resolving anterior crossbites when compared to conventional removable devices [11, 30]; therefore, it can achieve excellent results in a short time of therapy [1, 26, 27]. Gu and colleagues [25] reported an average time of treatment of 8.5 months in 17 consecutive patients (mean age, 9.7 years) with pseudo-class III malocclusion and anterior crossbite using a 2×4 appliance together with reverse headgear, and no relapse was detected after 1 year of follow-up; no retainers were placed.

In cases of posterior crossbites, when maxillary expansion is indicated, it can be carried out by adding a quad-helix to the 2×4 appliance [6, 13]. Further, the use of interarch elastics attached to lingual and buccal buttons has been suggested, as a complementary procedure to restore the functional contacts between malpositioned teeth [26].

4.2 Ectopic/impacted upper permanent central incisors

Another indication of the 2×4 appliance is at an early stage is the correction of ectopic or impacted permanent incisors. Once the etiological factor has been identified, it may be that the necessary space to be created to allow the adequate reposition of the affected tooth and bring it into its correct site in the dental arch [13]. 2×4 appliances can easily perform a careful space opening and also control the traction force magnitude and vector, with much more precision than with removable appliances [6]. In this respect, Das and co-workers [17] have established the determining factors to take on account for the successful alignment of an impacted incisor with the appliance: (i) the position and direction of the impacted tooth; (ii) the degree of root dilacerations; (iii) the degree of root development; and (iv) the presence of sufficient space for the impacted incisor.

4.3 Midline diastemas, alignment of rotated/spaced upper incisors, and maxillary anterior crowding

Once eliminated the local etiological factor for the diastema (e.g., mesiodens or abnormally implanted labial frenum), a sectional 2×4 appliance can be placed for achieving a better-controlled space closure and the alignment and leveling of the upper incisors. Sometimes, double-helical wire loops, inter-brackets elastomeric chains/elastics, and micromagnetic devices are added to facilitate the space closure [35]. The orthodontic midline diastema closure in mixed dentition has been classified into four categories [29]: (i) treatment involving mesial tipping of incisors, for the approximation of spaced tooth crowns only; (ii) treatment involving mesial bodily movements, for the approximation of both central incisors; (iii) treatment involving a decrease of enlarged overbite and intrusion of the upper incisors; and (iv) closure of the space as part of a more comprehensive orthodontic treatment.

4.4 Clinical recommendations and precautions

The orthodontic wires employed in the 2×4 technique must be thin in diameter to appropriately provide light, continuous and well-controlled forces over the incisors. These light orthodontic forces are applied for incisor derotations, alignment, and leveling, and are considered clinically safe and effective; according to the identified literature, initial archwires can be “0.012” to “0.016” NiTi (Nickel-Titanium alloy or Nitinol) (Titanium-Molybdenum-Titanium Alloy (TMA) wires can also be used); in a second phase, “0.016” stainless steel wires are employed; and finally, rectangular wires (“0.017” or “0.018” \times “0.025”) are placed. These wire arches are changed every two to four weeks. Dowsing *et al.* [13] and Naidu *et al.* [11] suggest in some cases the placement of a long supporting well-shaped stainless-steel tube on the archwire, filling the entire space between the first molar and the incisors. This tube strengthens the long unsupported span of the wire from distortions, due to occlusal forces. If additional space is required for incisor proclination, a compressed nickel-titanium open coil spring can be inserted. On the other hand, these same authors also recommend annealing the extra wire distal to the molar soldered tubes to allow the wire segment to be turned down against the tube; this procedure prevents the archwire from sliding forward, thus avoiding a possible arch length increase, and thus, the subsequent possible damage to cheek soft tissues, and potential undesirable movements of the first permanent molar.

4.5 Limitations

The present scoping review carefully followed the recommendations stated by Arksey and O'Malley for screening specific papers and extracting relevant data from them [18]. However, and after an exhaustive searching process, only relevant clinical case reports/series—which are highly prone to bias- and two clinical controlled trials were found and included in the review. This concern represented a considerable methodological heterogeneity, making it impossible to conduct a systematic

review/meta-analysis; given this, we intended to improve the quality of the study by performing a critical evaluation of the risk bias of the selected articles, using two well-validated and widely recognized specific scales. In addition, we also limited our searching to published articles written only in English (and one additional in Spanish); so, other language-relevant studies could be missed. Despite these limitations, and the fact that no cross-sectional and longitudinal observational were found, we are confident that sufficient reliable and useful information could be collected and synthesized, to aid clinicians in better understanding the clinical performance of the 2 × 4 appliance in mixed dentition children.

5. Conclusions

The 2 × 4 appliance is suitable, versatile, and very useful for mixed dentition patients with mild or severe malocclusions, because of the light, continuous, and well-controlled orthodontic forces applied, particularly when removable appliance usage is a critical problem. Therefore, this fixed orthodontic device can be used in different clinical situations with only negligible alterations and a few disadvantages regarding traditional removable approaches. The clinical utility of the 2 × 4 appliance at early ages has been well documented for the orthodontic management of relatively common malocclusal conditions, such as incisor crowdings or rotations, anterior and posterior crossbites, ectopic erupted upper incisors, and midline diastemas.

AUTHOR CONTRIBUTIONS

GHG, EYG, and SRR—conceived the presented idea and designed the research study. MRB, AGR, and APG—supervised the implementation of the article electronic/manual search. AGR and APG—drafted the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Amaury Pozos-Guillén is serving as one of the Editorial Board members of this journal. We declare that Amaury Pozos-Guillén had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to BB.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.jocpd.com/files/article/1600043732670791680/attachment/Supplementary%20material.docx>.

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