

REVIEW

Space maintenance controversies in pediatric dentistry—a scoping review

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Abstract

Space maintainers (SMs) serve as a key component in interceptive orthodontics, helping to avoid the need for more invasive treatments later on. This scoping review aims to assess the necessity and the controversy of using space maintainers, by comparing and analysing the dental and occlusion outcomes of children who received SMs with those who did not receive any treatment following the early loss of primary teeth. Databases such as PubMed, Science Direct, Wiley and ProQuest were examined using the PCC framework (Population, Concept, Context), following specific eligibility criteria. Titles and abstracts were screened, and full-text articles were critically assessed followed by the construction of the data charting table. A total of 901 were screened, and 17 relevant articles were included. The findings suggested that SMs could be effective in maintaining arch integrity and preventing future malocclusions. However, the literature revealed several key gaps and controversies in the use of SMs, particularly in terms of long-term effectiveness, patient compliance, cost and the occurrence of potential complications. The findings of this review seem to be helpful for clinicians in deciding when the SM is necessary versus when the natural closure is expected; also in optimising patient outcomes and reducing unnecessary treatments by incorporating these findings into their practice making more educated individualized treatment decisions, and using a risk-based strategy; as well as in improving parental counselling and patient education, which help increase compliance, especially when it comes to removable appliances. However, the disparities in study designs, inadequate long-term data and unclear therapeutic guidelines might complicate evidence-based decision-making. To address these gaps, the focus on longitudinal, standardized clinical trials that assess the true efficacy of SMs over time, studies that compare the effectiveness of fixed versus removable SMs, and patient compliance variables are recommended for future research.

Keywords

Band and loop; Controversy; Orthodontics; Preventive dentistry; Removable appliances; Space regainers; Space maintainers

1. Introduction

The premature loss of primary teeth presents a clinical challenge in pediatric dentistry, as it can compromise arch integrity and impact the alignment of successor teeth, necessitating the use of space maintainers in many cases [1]. Studies comparing different space maintainer designs have emphasized the importance of individualized planning based on the stage of dental development in children [2]. The development and growth of the dental arch, esthetics, mastication and speech are altogether dependent on the preservation of the primary dentition, and it also promotes normal function and expected growth that is essential for creating room for the permanent successors to eventually erupt [2]. A malocclusion in permanent teeth may arise from the premature extraction of primary teeth, which could cause space loss in the developing dentition [3].

Early interceptive treatment and prevention of malocclusion in primary and early mixed dentition stages is crucial to avoid the development of arch disturbances and anomalies, this can help reduce or even eliminate the need for comprehensive orthodontic treatment later on [3]. It is widely accepted that premature loss of primary teeth may cause adverse changes in either or both permanent and primary teeth, reducing arch length which can exacerbate crowding and malocclusion [4]. The safest approach to address this issue is to use a space maintainer [5]. The space maintainer (SM) is defined as “a device that can be fixed or removable and is mainly utilized to maintain the space created by the lost primary tooth or teeth until the eruption of their successors” [6]. The most important function of these appliances is to maintain the mesiodistal relationships within the affected dental arch [6].

There are different types of fixed space maintainers, such as

crown-loop space maintainers, band-loop space maintainers, trans palatal arch space maintainers, lower lingual holding arch space maintainers and Nance appliances. Although fixed space maintainers are more commonly used, various types of removable partial dentures have also been used as space maintainers [7]. Fixed space maintainers have shown favorable clinical performance, with reported longevity rates ranging between 70% and 85% in certain designs [2].

Post-operative care and instructions are important to maintain the space maintainer's condition, children usually intervene with the space maintainer with their tongue, which can lead to dislodgment over time, and chewing sticky food can loosen the appliance [8]. The use of space maintainers is indicated in various clinical situations, including early loss of primary teeth and delayed eruption of permanent teeth. Some studies also suggest ensuring sufficient bone coverage—such as 1 mm of bone—before appliance placement [9].

On the other hand, the space maintainers are contraindicated in the following situations: When there is no bone coverage; when the root of permanent teeth makes up only two-thirds of the tooth; When the permanent teeth have not erupted and the space needs to be sealed; or when the mesiodistal width of the primary crown is smaller than that of the permanent teeth [8]. Therefore, the space maintainer is a controversial subject.

A controversial study is any topic/text that evokes opposing feelings or points of view and lends itself to a search engine inquiry [10]. In dentistry, controversial research has a significant role in patient care and clinical practice, for example, the debate surrounding the use of fluoride and mercury [11], along with research on progress in resolving contentious endodontics topics [12]. This type of study highlighted how critical it was to discuss contentious issues in dentistry to provide evidence-based, patient-centred care. There is a controversy regarding the necessity of space maintainers after the early loss of a primary tooth [13]. A limited number of evidence supported using space maintainers to prevent or reduce the severity of malocclusions in the permanent dentition [13]. When deciding whether to use a space maintainer, the possibility of occlusal disturbance caused by not using it with the risk of plaque accumulation and caries caused by the appliance should be considered [13]. Therefore, the objective of this study was to assess the necessity of space maintainers in children, by conducting a scoping review to compare and analyze the dental and occlusion outcomes of children who received space maintainers with those who did not receive any treatment following the early loss of primary teeth.

2. Materials and method

2.1 Study design

This scoping review was structured using the methodology that was reported by Arksey & O'Malley and later enhanced by the Joanna Briggs Institute (JBI) framework for a scoping review [14]. The JBI framework refers to a systematic evidence-based approach to healthcare research, synthesis and implementation. So this method was developed by the Joanna Briggs Institute, which is an international research organization based at the University of Adelaide, Australia. The JBI framework

focuses on improving global health outcomes through the use of high-quality evidence-based practices [14]. The JBI enhanced this methodology by providing more detailed guidance on each stage, developing comprehensive search strategies, utilizing standardized data extraction tools and ensuring transparent reporting of results [14]. According to JBI's scoping review manual, the Population, Concept and Context (PCC) mnemonic was advised as a tool to develop a concise and meaningful title for a scoping review. A scoping study does not require specific outcomes, interventions or phenomena of interest to be stated; nonetheless, the notion being studied may have elements of any of these [15]. This scoping review was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews guidelines (PRISMA-ScR), and the protocol was approved by all authors.

In the PCC tool, the population (P) was the age and other qualifying factors that qualify participants for the scoping review's objectives, and the review question should be included in detail as they were important characteristics of the participants. In certain cases, the participants themselves did not constitute a valid condition for inclusion. For instance, it might not be helpful or appropriate to include information about the kinds of participants in that research in a scoping review that focuses on mapping the kinds and specifics of research designs that have been employed in a certain subject. Whereas Concept (C) was to direct the scope and depth of the investigation, the core idea that the scoping review looked at should be expressed clearly. This could contain information on topics covered in a typical systematic review, like the interventions, phenomena of interest and/or outcomes. The Context (C) could comprise cultural elements like locality and/or certain racial or gender-based hobbies. Contextual information occasionally includes specifics about the environment [15].

2.2 Research question and study tools

Are space maintainers essential? To answer this question, a scoping review was conducted and followed the population, concept and context (PCC) tool. Population (P) was children in the mixed dentition phase, usually between the ages of 6 and 12 years, and had experienced premature loss of their primary teeth. Whereas Concept (C) was the use of space maintainer or not, and Context (C) was the clinical settings or studies addressing the impact of space maintainers.

2.3 Eligibility criteria

2.3.1 Inclusion criteria

1. Research Design: Randomized Controlled Trials (RCTs), case series, systematic reviews/meta-analyses, cross-sectional observational studies, and cohort studies that evaluated the effectiveness and usage of space maintainers.

2. Population: Children who had an early loss of their primary teeth and were in the mixed dentition phase (usually between the ages of 6 and 12 years). This age represented the period in which space maintainers were mostly used.

3. Concept: The use of space maintainer or not, including clinical outcomes and effects.

4. Context: Males and females, all types of space maintainers to give a comprehensive overview.

5. Publication Date: Research that had been published in the past ten years (from January 2014 to December 2024). A 10-year timeframe was selected to ensure having up-to-date evidence while allowing for adequate data to identify meaningful trends in space maintainer use and effectiveness.

6. Language: Research articles that had been published in Arabic or English languages to ensure full understanding of the context.

7. Availability: Full-text articles must be accessible for evaluation.

2.3.2 Exclusion criteria

Studies were excluded if any of the following criteria was/were applied to the study:

1. Publication Date: Before January 2014 or after December 2024.

2. Language: The research was not published in Arabic or English languages to avoid translation bias or misunderstanding.

3. Accessibility: Full-text articles could not be found, which prevented the proper data extraction.

4. Article type: Works without complete data, such as letters, editorials, opinion pieces and conference abstracts, were not included in the study, as they did not provide the required evidence and data needed for a structured review.

2.4 Study screening and selection

A structured electronic search was conducted on four electronic databases: PubMed; ProQuest; Wiley and Science Direct. The following keywords were used, alone or in combination: Space maintenance, Orthodontic space maintenance, Preventive dentistry, Removable appliances, Band and loop, Controversy and Space regaining. This search strategy was appropriately adapted for each database.

In each database, the following search algorithm was employed: space maintenance OR space regainer AND indication AND controversy AND removable appliance AND advantages. Titles and abstracts obtained from electronic searches were meticulously reviewed and screened by two independent reviewers, studies that did not meet the inclusion criteria were excluded at this stage. Any study that seemed to be relevant was moved to a full-text review. Any disagreements or discrepancies between the reviewers were discussed and resolved through consensus. If a consensus could not be reached, a third reviewer was consulted to make the final decision. Additionally, the reference lists of the reviewed articles were manually searched for any additional studies that may have been overlooked in the initial search. In instances where important data were missing from an article, further actions were taken.

2.5 Data charting and results synthesis

Data was extracted from each included article and the following sections of information were summarized and recorded: the name of the first author, the year of publication, the country of the study, the methodological design, the type of SM and

their outcomes, as well as the main findings. For observational studies either cross-sectional or longitudinal, details such as the target population, sample size, and follow-up period -in the case of cohort designs-were also noted. Two reviewers independently collected all items, and any disagreements or discrepancies were resolved through discussion with the third reviewer.

3. Results

3.1 Epidemiology of data

A significant heterogeneity in the included studies was found, in terms of the sample size, methodology and follow-up duration, which might affect the findings of this review. Differences in sample size may affect generalizability, with larger samples offering more reliable outcomes. Moreover, the variations in the study design (methodology) could lead to variation in the reported effects, while differences in the follow-up periods might lead to over or under-stimulation of the effect of space maintainers. Such variability may lead to inconsistent findings, warranting cautious interpretation.

Regarding the selection of studies, a total of 901 articles were identified in the four different electronic databases (PubMed, Science Direct, Wiley and ProQuest), and around 501 articles remained after duplicates were removed. After the abstract screening, 134 full-text articles were assessed for eligibility. Seventeen articles met the inclusion criteria and were incorporated into this review in this scoping review, as shown in Fig. 1. The data epidemiology and charting are presented in **Supplementary Table 1** (Ref. [1, 2, 5, 6, 9, 16–27]).

The included studies were primarily focused on the use of space maintainers in pediatric dentistry and compared the effectiveness, longevity, clinical outcomes and patient satisfaction of fixed and removable space maintainers. These studies focused on children who experienced the premature loss of primary teeth and required intervention to prevent space loss and occlusal problems. The included studies involved two review articles; four systematic reviews; two case series; three randomized controlled trials; two cross-sectional observational studies; two longitudinal studies; one Novel approach; and one comparative clinical study.

Regarding the country of authors, most articles were conducted in India and Saudi Arabia. Other included countries were Turkey, Iran, Taiwan, Italy, the United Arab Emirates and Indonesia. The publication dates ranged from January 2014 to December 2024. The main characteristics of numerical data, findings and conclusions from these articles are summarized in **Supplementary Table 2** (Ref. [1, 2, 5, 6, 9, 16–27]). The summary of different research perspectives on using space maintainers, whether it supported the use of space maintainers after the premature loss of the primary tooth or not, is shown in Table 1 (Ref. [1, 2, 5, 6, 9, 16–27]).

3.2 Types of space maintainers and effectiveness

• Space maintainers and effectiveness: Most of the research (around 82%) corroborated that SMs assisted in avoiding den-

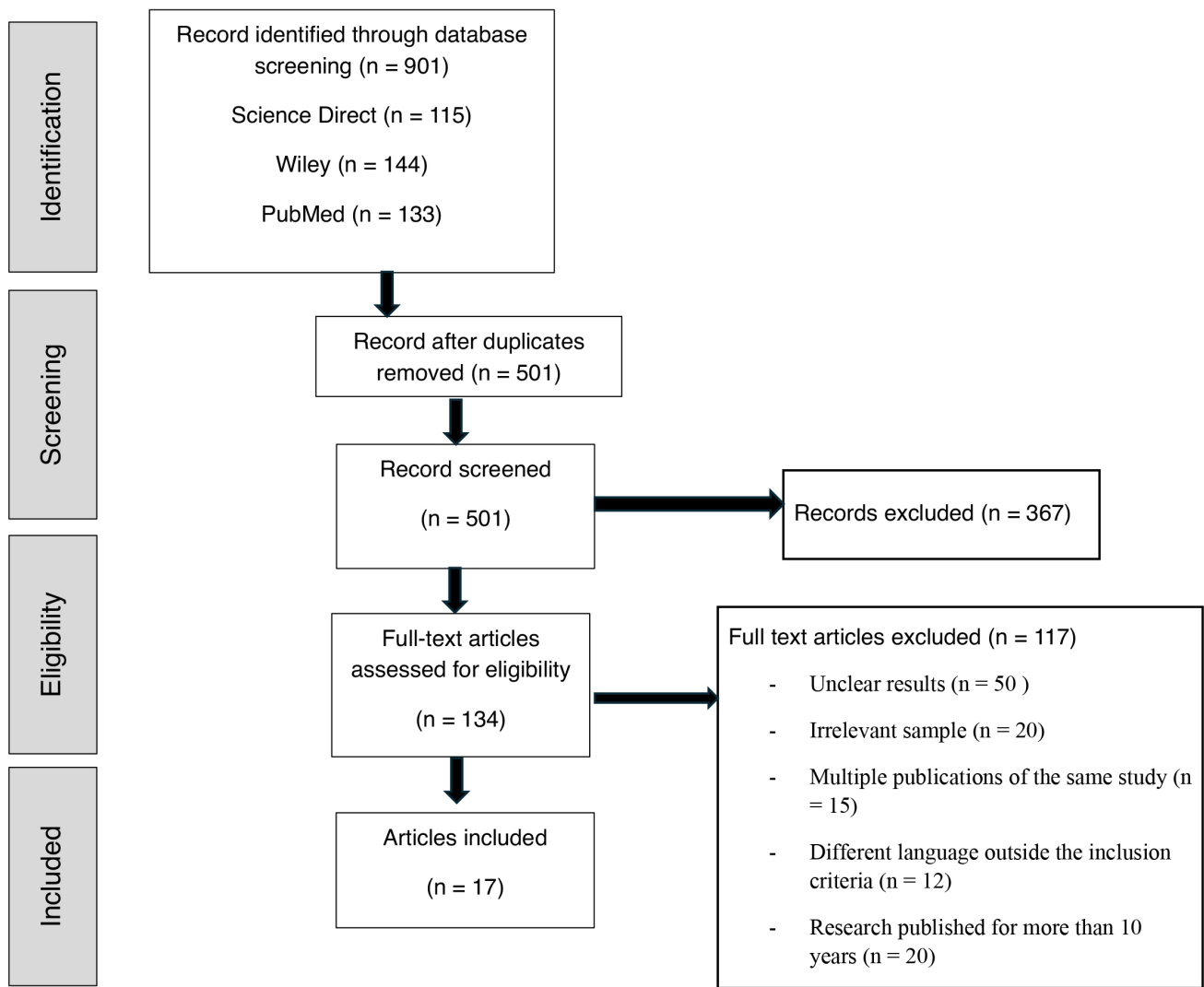


FIGURE 1. Flowchart of studies.

tal crowding and obstructing dental eruptions. They helped in maintaining the dental arch and facilitated the eruption of permanent teeth when used immediately following the loss of primary teeth. For instance, Setia *et al.* [16] and Khalaf *et al.* [17] reported that SMs considerably contributed to the reduction of space maintenance issues during the mixed dentition stage. They found that space maintainers were effective in preventing alignment issues.

- **Fixed space maintainers (Band-and-Loop):** The band-and-loop was the most frequently used fixed device. These devices had a success rate of around 85–90% in preserving space following premature tooth loss, especially in cases of unilateral molar loss [16, 18]. According to Ramakrishnan [19] and Tahiririan [5], patient oral hygiene and appropriate maintenance significantly impacted the long-term performance of band-and-loop devices.

- **Bonded space maintainers:** Although research by Deshpande [20] showed that they had a higher failure rate of 30–40%, because of issues like de-bonding and inadequate adhesion. However, bonded space maintainers were still a popular choice [20]. Despite these difficulties, bonded devices were

valued for their visual appeal and were mainly used for anterior teeth. Nevertheless, according to research like Setia *et al.* [16] and Ramakrishnan [19], individuals with poor oral hygiene had a higher failure rate.

- **Removable space maintainers:** Research by Argwal [1] and Cengiz and Karayilmaz [21] showed that these devices could be useful, especially for kids with compromised dentition, but that patient compliance was crucial to their effectiveness. Failure was commonly attributed to non-compliance. For instance, Cengiz and Karayilmaz [21] found that while removable devices functioned effectively when patients followed their treatment plans, failure rates sharply increased when adherence was poor.

3.3 Comparisons of different types of space maintainers

- **Removable vs. Fixed Devices:** Approximately 64% of research (e.g., Argwal [1] and Cengiz and Karayilmaz [21]) indicated that in cases when patients were cooperative, removable space maintainers would be useful. As a result, fixed space maintainers especially band-and-loop devices were thought to

TABLE 1. Summary of studies supporting or opposing space maintainers.

Study's name	Support the use of space maintainers	Does Not support the use of space maintainers
A Modified Removable Space Maintainer for Compromised Dentition of Children [1]	Yes (Modified removable space maintainers are suitable for uncooperative children)	
Comparative Evaluation of Fixed Functional Cantilever Space Maintainer and Fixed Nonfunctional Space Maintainer [2]	Yes (Considering individual patient factors)	
Comparison of the longevity of prefabricated and conventional bands and loops in children's primary teeth [5]	Yes	
Modern concepts of space maintainers and space regainers [6]	Yes	
Space Maintainer [9]	Yes	
Banded vs Bonded Space Maintainers: Finding Better Way Out [16]	Yes	
Clinical Effectiveness of Space Maintainers and Space Regainers in the Mixed Dentition [17]		No (Need more high-quality research)
Clinical Evaluation for Space Maintainer after Unilateral Loss of Primary First Molar in the Early Mixed Dentition Stage [18]	According to the study, a space maintainer may be required following the unilateral loss of a primary first molar, depending on the time since extraction and facial pattern. It suggests evaluating each situation to ascertain necessity rather than categorically endorsing or opposing space maintainers	
The survival rate of different fixed posterior space maintainers used in Pediatric Dentistry [19]	Lacks sufficient evidence to properly support the use of space maintainers	
Survival of Bonded Space Maintainers [20]	Yes	
Comparative Evaluation of the Clinical Success of 3D-Printed Space Maintainers and Band-Loop Space Maintainers [21]	Yes	
Clinical Effectiveness of Fibre-reinforced Composite Space Maintainer and Band and Loop Space Maintainer in a Pediatric Patient [22]	Yes (Fibre-reinforced Composite Space Maintainer is effective for short-term use only)	
Long-term space changes after premature loss of a primary maxillary first molar [23]		Following the early loss of a primary maxillary first molar, space maintainers were not required
Clinical Evaluation of Short-Term Space Variation Following Premature Loss of Primary Second Molar at Early Permanent Dentition Stage [24]	Yes	
Efficacy of clear aligners vs rapid palatal expanders on palatal volume and surface area in mixed dentition patients [25]	RME is more effective for skeletal expansion, while clear aligners may be useful for dentoalveolar modifications. The study does not directly address space maintainers	
Functional Band and Loop Space Maintainers in Children [26]	Yes (Especially effective band and loop space maintainers, which support children's arch integrity, masticatory function and space maintenance)	
Biogenic Tooth-Integrated Fixed Functional Space Maintainer for Pediatric Use [27]	Yes	

RME: Rapid Maxillary Expansion.

be more dependable because of their stability and reduced failure rates. For children who did not follow treatment plans, studies like Ramakrishnan [19] and Deshpande [20] indicated that fixed devices were preferable.

- There was only one study that compared the 3D-printed space maintainers to band-loop devices, it discovered that while 3D-printed devices provided a more personalized fit and comfort, they were less useful than traditional devices because of their higher cost and longer sitting time. From a cost-effectiveness perspective, 3D printing was less beneficial than traditional devices as the clinical results were comparable [21].

- Band-and-loop vs. Fiber-reinforced composite: Kalaskar contrasted band-and-loop devices with fibre-reinforced composite space maintainers [22]. Although composite maintainers were shown to have reduced failure rates and greater aesthetic quality, their cost and production complexity prevented widespread adoption. On the other hand, because of their dependability and affordability, band-and-loop devices continued to be used more frequently [22].

3.4 Group finding according to patient condition

- In cases of unilateral space loss, particularly in the mandible, space maintainers should be placed promptly within 6 to 9 months post-extraction to prevent space loss that might lead to occlusion problems. For maxillary space loss, particularly with premature loss of a primary first molar, space maintainers were generally not required, as the natural arch development compensated for the loss. Treatment plans should be tailored based on the timing of extraction and the individual facial growth pattern to ensure effective space management [18, 23].

- In the late mixed dentition cases, the use of fixed space maintainers and regainers was crucial for maintaining space for the eruption of permanent teeth, but their effectiveness was not universally consistent. The mixed evidence on their ability to maintain arch length and prevent crowding suggested that individual patient factors should play a significant role in treatment decisions. Clinicians should be cautious about relying solely on current evidence, as the long-term outcomes of these devices are still unclear. There is a pressing need for higher-quality, longitudinal studies to better understand their efficacy and guide future treatment planning.

- In the early mixed dentition cases, the premature loss of primary molars caused significant space reduction. The space loss occurred rapidly within the first 3 weeks, underscoring the need for immediate intervention with space maintainers to prevent long-term orthodontic issues. However, there was no correlation between space loss and the age or eruption stage of successor premolars, indicating that other factors, such as facial growth patterns, might influence space loss. The premature loss of primary teeth also impacted arch integrity, leading to the tipping of adjacent teeth and potential malocclusion.

3.5 Long-term outcomes and space maintenance

- Long-term space changes following premature tooth loss: Research by Bindayel [24] and Lin [23] showed that prompt

space maintainer placement greatly decreased the long-term risk of crowding and malocclusion. It had been demonstrated that early management (within six months of tooth loss) improved permanent dental alignment and preserved space. With a 90% success rate, the band-and-loop proved very good at preserving space over time.

- Clear aligners vs. Rapid palatal expanders: Bruni's study investigated the differences between rapid palatal expanders and clear aligners. Expanders were found to be more successful in arch development and space maintenance, especially in patients requiring palatal expansion, even though transparent aligners were chosen for their aesthetic appeal. The rapid palatal expanders showed more efficacy in preserving space than clear aligners, despite their popularity due to their aesthetic appeal [25].

3.6 Disagreement among studies

- Compliance and patient factors: The contribution of patient compliance to the effectiveness of removable space maintainers was a major point of controversy. Removable devices were found to be highly beneficial when patients adhered to treatment protocols, according to studies like Argwal [1] and Bindayel [23]. For patients with low compliance, however, fixed devices were more dependable, according to Ramakrishnan [19] and Deshpande [20].

- Bonded space maintainers: Views regarding the longevity of these maintainers were varied. Bonded devices functioned well for patients who practised good dental hygiene, according to Setia *et al.* [16]. However, Deshpande [20] and Ramakrishnan [19] discovered that de-bonding resulted in higher failure rates than banded devices.

- 3D-printed space maintainers: There is still debate over the clinical superiority of 3D-printed space maintainers over conventional equipment. Although Cengiz and Karayilmaz [21] compared the clinical performance of band-loop and 3D-printed space maintainers, they found that the 3D printed were more durable and had a higher resistance to wear, fracture and deformation, which resulted in fewer failures and a lower need for adjustments over time. On the other hand, band-loop space maintainers required more frequent maintenance due to their greater failure rate, which included wear and fractures. According to the study, patients adapted to 3D-printed models much more easily, and their smoother surfaces and superior fit made them more comfortable, which increased patient acceptance. However, band-loop space maintainers frequently caused greater discomfort and necessitated more modifications.

Although both types were successful in preserving arch space, the long-term results and clinical success rates of 3D-printed space maintainers were superior. However, the study also pointed out that 3D-printed space maintainers were expensive to build because they needed specific tools and knowledge. Band-loop space maintainers were less costly and simpler to make, but they were not as accurate or long-lasting as the 3D-printed ones. Even though the 3D-printed models were more expensive initially, their long-term durability and lower maintenance requirements could eventually result in cost savings, and increase their overall worth.

4. Discussion

The ongoing debate over the use of space maintainers in pediatric dentistry was examined in this scoping review study. A scoping review is a new method for gathering evidence that differs from systematic reviews in its aims. The main aim of the scoping review was to give an overview of existing research without trying to provide a definitive answer for clinical decision-making. It supported the identification and mapped out the available evidence [15]. Scoping reviews collected a variety of study types to summarize and synthesize information, which could help inform practices, programs and policies, as well as guide future research directions. Since the goal of the scoping review was different from that of a systematic review, the questions it addressed might not fit the PICO (Patient/Intervention/Comparison/Outcome) framework. Instead, the PCC framework might be more appropriate [28, 29].

Preserving the space left by the premature loss of primary teeth was essential until the permanent successor appeared. Effective space management was key to checking dental development, and the use of space maintainers could prevent future extractions or the need for complex orthodontic procedures. The type of space maintainer used depended on factors such as the child's age, dental development and occlusion. However, there was limited research on the clinical effectiveness of space maintainers and how different design and construction factors impacted their durability [30].

This scoping review was carried out to map a thorough overview of the literature, gap analysis, concept clarification within the field, and analysis of the methodologies used in earlier research [31]. This method offered a comprehensive summary of the existing literature, laying the groundwork for a more in-depth comprehension of using space maintainers in children, which was the main objective of this investigation. The efficacy of SMs in maintaining arch integrity, especially in situations of early primary molar loss, was supported by the majority of examined research [32, 33]. This scoping review explored the available evidence on space maintainers and revealed significant variations in study outcomes, methodologies and interpretations. While some studies supported the use of the SMs, others argued it, as shown in Table 1.

4.1 Effectiveness of space maintainers and regainers in the mixed dentition: a controversial evidence-based

In children during the mixed dentition period, the effectiveness of space maintainers and regainers in preserving arch length and preventing mild to moderate crowding was poorly supported by evidence [31]. For example, Khalaf *et al.* [17] assessed the clinical effectiveness of space maintainers and regainers but found inconsistent results regarding their long-term impact on arch length. Certain research indicated that the early loss of the first primary molar resulted in a decreased arch length, necessitating the use of space maintainers [24]. Nonetheless, additional studies suggested that arch length did not change after the premature loss of the first primary molar, indicating that space maintainers might not be necessary in all

cases [9, 23]. Moreover, there was very limited data supporting the efficacy of certain space maintainers in maintaining arch length and preventing incisor crowding during the mixed dentition stage, such as lip bumpers, trans palatal arch devices and lower lingual arches [16, 26].

4.2 Variability in the effectiveness of space maintainers and emerging approaches in pediatric dentistry

The variation in results highlights the necessity of customized treatment planning, stressing that the clinician's evaluation and the patient's particular orofacial features should inform the choice to employ a space maintainer. Space loss in the mandible was found to be more than maxilla. However, during a follow-up period of 6–24 months, it was noticed that the amount of loss didn't affect the arch with length [34]. Due to variations in study design, definitions of treatment success and methodological errors, Casaña-Ruiz *et al.* [34] discovered that the efficacy of space maintainers in pediatric patients varied greatly. The type of device, patient compliance, cost and the practitioner's level of experience all affect space maintainers' success rates.

Banded and bonded space maintainers were compared by Setia *et al.* [16], who pointed out variations in clinical effectiveness, benefits and drawbacks. Mosharrafian *et al.* [18] evaluated space maintenance results after the unilateral loss of a primary first molar in the early mixed dentition stage, whereas Vinothini *et al.* [33] investigated the efficacy of functional band and loop space maintainers. Additionally, Cengiz & Karayilmaz [21] examined the clinical efficacy of 3D-printed space maintainers in comparison to conventional band-loop designs, while Bindayel [23] examined short-term space fluctuations following the premature loss of a primary second molar.

While Lin & Lin [24] assessed long-term space changes following the early loss of a primary maxillary first molar, Khalaf *et al.* [17] conducted a systematic study of the clinical efficacy of space maintainers and regainers in the mixed dentition. While Bruni *et al.* [25] examined the effectiveness of transparent aligners in comparison to quick palatal expanders for arch development in patients with mixed dentition, Ramakrishnan *et al.* [19] examined the survival rates of various fixed posterior space maintainers. Furthermore, Kamki *et al.* [22] investigated the clinical performance of fibre-reinforced composite space maintainers, while Deshpande *et al.* [20] carried out a systematic review of the durability of bonded space maintainers. A biogenic tooth-integrated fixed functional space maintainer was presented by Chandra *et al.* [35] in a new manner for use with children.

4.3 Ensuring the research validity in space maintainer studies

To guarantee the validity of the results, a critical assessment of the research methodology of the included articles was performed. Various sample sizes have been reported in numerous studies, some of which used a small sample size that might not correctly represent the whole population. The study of Mosharrafian *et al.* [18] for instance, concentrated on unilat-

eral primary molar loss but had a short follow-up time, which might have an impact on the long-term evaluation of space maintenance. The presented results might also be impacted by various biases, such as operator variability, selection bias and variations in follow-up periods. To improve the validity of findings, future studies are required to strive for a larger more uniform sample size.

4.4 Impact of the study design on the clinical outcomes

The assessment of results was also significantly impacted by the variation in study designs. Space alterations after premature primary molar loss have been evaluated in studies like those by Bindayel [23] and Lin [24], but direct comparisons were difficult because of methodological discrepancies, including variances in imaging techniques and follow-up durations. Additionally, whereas some research evaluated the clinical efficacy of SMs using randomized controlled trials [17], others relied on observational or retrospective techniques, which limited the strength of conclusions. In clinical practice, using non-randomized approaches may limit the ability to demonstrate causal correlations, add potential biases, and impact the findings' generalizability to a variety of patient populations. If these discrepancies are addressed in further studies, establishing evidence-based recommendations for the use of SMs will be feasible.

4.5 The importance of the individual treatment plan for the use of the space maintainer in each patient

From a clinical perspective, a case-by-case approach would be appropriate in utilizing space maintainers in general. Samal's work emphasized the importance of personalized treatment planning [9]. SMs may not always be necessary, especially when permanent tooth eruption is about to occur or when the adjacent teeth may naturally keep their distance from one another. Modern ideas of space maintainers and space regainers were presented in another study, which concentrated on circumstances where their participation might be avoided [6]. However, the capacity to conclusively ascertain the long-term consequences and hazards associated with SMs usage was limited by the existing insufficiency of long-term clinical data.

Clinical decision-making was impacted by this research gap because practitioners might be reluctant to implement SMs if it was unknown how long-lasting and successful they would be. More long-term clinical research is required to develop more trustworthy criteria for choosing cases that would benefit from the SM intervention. To support evidence-based decision-making, future studies are required to focus on examining the long-term efficacy, possible side effects and overall influence of SMs on dental development.

4.6 The effects of socioeconomic factors and the compliance of the patient on the use of space maintainers

Socioeconomic factors have a big impact on SMs usage and treatment outcomes. Some families may find the expense of

SMs prohibitive, especially in areas where access to pediatric dentistry is scarce. After investigating the financial and patient compliance difficulties, Setia *et al.* [16] concluded that better patient education or less expensive options would improve adherence. Additionally, Vinothini *et al.* [26] stressed the importance of compliance, especially with removable SMs that need to be used consistently to be successful. Overall treatment success rates could be raised by investigating more affordable options and methods to increase patient adherence.

4.7 Comparing the longevity and effectiveness of fixed and removable space maintainers

The necessity of customized treatment planning was further shown by a direct comparison of fixed and removable SMs. Sathyaprasad's study examined the variations in longevity and maintenance needs between fixed-functional and fixed-nonfunctional cantilever SMs [2]. Bonded space maintainers' survival rates were examined by Deshpande who emphasized that although fixed SMs remove compliance problems, they still have drawbacks including higher plaque buildup and the requirement for more dental operations [20]. Cengiz and Karayilmaz on the other hand, looked into 3D-printed space maintainers, providing a contemporary substitute that might help close the gap between conventional fixed and detachable designs [21]. To inform therapeutic decision-making, studies contrasting the long-term efficacy, maintenance needs and survival rates of the two types are required.

4.8 Limitations of the scoping review methodology

Regarding limitations of the scoping review method, it included difficulties in defining search terms due to varying terminology across the literature, challenges in determining the review's scope since new methodologies were often not fully described in abstracts, and the risk of missing important details when methodologies were only documented in supplementary materials [36].

The outcomes of this scoping review were impacted by several limitations, important data might not be overlooked due to limited access to relevant studies and an inadequate search strategy. Similarly, extracting and synthesizing data were challenging because of inconsistencies in reporting among sources. Additionally, time and budget constraints prevented a more thorough analysis. These issues restricted the overall accuracy and completeness of the study, better training, more precise methodological guidelines, and more stringent quality control in publishing scoping reviews were necessary to address these issues.

Improving the conduct and reporting of the scoping review is recommended to achieve the objectives of the review. Following the framework of Arksey and O'Malley was the foundational approach, however, it should be expanded with JBI guidelines [37]. The JBI guidelines together with the Arksey and O'Malley framework offered a methodical way to conduct scoping reviews. However, these frameworks have intrinsic constraints that might have affected the interpretation of the results. Arksey and O'Malley's approach, for example,

permitted flexibility in the review process, which could be an advantage but might also result in variations in the interpretation and presentation of data. This adaptability might have affected the conclusions' coherence, especially when combining various studies with different approaches.

Another limitation was the possible bias in the selection of research of different quality because the JBI criteria emphasized thorough data extraction and critical evaluation but did not mandate a formal quality assessment for included studies. Although mapping the body of existing literature was the aim of scoping reviews, this method could make it difficult to make definitive judgments regarding the quality of the evidence. These restrictions should be taken into account when evaluating the results because they might have affected the results' level of analysis and generalizability.

4.9 Future directions of the research in the evidence-based space maintainers

A comprehensive evaluation of space maintainers' effectiveness is necessary to guarantee that they avoid malocclusion and retain the space for permanent teeth successfully. To assess the success rates and potential drawbacks of various space maintainer types, such as fixed and removable designs, long-term clinical studies could be the main focus of future research. Comparability between research would be improved by standardized approaches, such as uniform imaging methods and evaluation standards. To find the best designs for different clinical situations, it is also important to carefully consider aspects like durability, patient compliance, cost and impacts on nearby teeth. The establishment of evidence-based clinical guidelines may also benefit from joint multi-centre research.

4.10 Practical implications

The lack of guidelines and agreement on clinical standards regarding the appropriate use of space maintainers and their optimal duration indicated that clinicians must assess each case individually. These gaps highlighted the need for evidence-based recommendations, which can only be established through carefully designed clinical research to resolve existing controversies and provide clearer clinical guidelines.

5. Conclusions

The findings of this review seem to be helpful for clinicians in deciding when the SM is necessary versus when the natural closure is expected; also in optimising patient outcomes and reducing unnecessary treatments by incorporating these findings into their practice making more educated individualized treatment decisions, and using a risk-based strategy; as well as in improving parental counselling and patient education, which help increase compliance, especially when it comes to removable appliances. However, the disparities in study designs, inadequate long-term data, and unclear therapeutic guidelines might complicate evidence-based decision-making. To address these gaps, the focus on longitudinal, standardized clinical trials that assess the true efficacy of SMs over time, studies that compare the effectiveness of fixed versus remov-

able SMs, and patient compliance variables are recommended for future research.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article.

AUTHOR CONTRIBUTIONS

AA—was the main and corresponding author who had the idea and the plan for this research, wrote the manuscript, and was the supervisor of the entire research process; contributed to editorial changes in the manuscript and handled the submission for publication. BQ and RG—performed the electronic search, retrieved and reviewed data and summarized the results. All authors reviewed and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.jocpd.com/files/article/1985179840456605696/attachment/Supplementary%20material.docx>.

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How to cite this article: Abeer Alnamankany, Basmah Qumqumji, Rafah Ghous. Space maintenance controversies in pediatric dentistry—a scoping review. *Journal of Clinical Pediatric Dentistry*. 2025; 49(6): 1–10. doi: 10.22514/jocpd.2025.121.