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Long-term stability of posterior crossbite correction, treated in the mixed or permanent dentition of growing children: A systematic review and meta-analysis

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Abstract

When treating posterior crossbite, the primary goal is to achieve long-term crossbite correction. The majority of studies however focus on relapse of the increase in the transverse dimension, but not relapse of the crossbite itself, which is an essential outcome. The aim of the present study was to determine long-term stability (2 years minimum post-treatment) of posterior crossbite correction, treated in mixed or early permanent dentitions of growing children. Following registration in PROSPERO (CRD42022348858), an electronic literature search including PubMed, Embase, Web of Science, the Cochrane Library, and a manual search were conducted up to January 2023, to identify longitudinal studies looking into the long-term stability of crossbite correction in growing children. Data extraction and risk of bias assessment were carried out, and subsequently, a random-effects meta-analyses models were used to calculate estimates for relapse of the crossbite and relapse at the transverse level. Twenty-two studies were included, of varying designs and quality, representing 1076 treated patients, with different expansion appliances and protocols. Meta-analysis results showed that 19.5% (95% CI: 15%; 25%) of patients present with relapse of posterior crossbite at long-term follow-up. At the transverse level, 19.3% of the total expansion (including overexpansion) relapsed (95% CI: 13%; 27%) regardless of whether there a was relapse of the crossbite itself. Data from existing studies, with a moderate level of evidence, indicate that the long-term stability of posterior crossbite correction in growing children is unfavourable in roughly 1 in 5 growing children, with crossbite relapse long-term. On average, 19% of the maxillary expansion performed (including overexpansion) relapses long-term, which may occur in cases with or without relapse of the crossbite.

KEYWORDS
long-term stability, meta-analysis, posterior crossbite, systematic review

1 | INTRODUCTION

Posterior crossbite, a common malocclusion, can occur unilaterally or bilaterally. When occurring unilaterally, it can lead to functional deviation of the mandible towards the crossbite side so that the child achieves better tooth interdigitation. The abnormal mandibular functional displacement associated with a unilateral posterior crossbite has been proposed to have negative long-term consequences on jaw growth and occlusal development, potentially leading to dentofacial asymmetry.[1]

Based on epidemiological data, the prevalence of unilateral posterior crossbite in the mixed dentition varies between 4% and 30%.[2] Several appliance designs and expansion protocols are used for maxillary expansion depending on factors such as patient age, oral hygiene, practitioner preference and experience. Regardless of how the expansion is carried out, long-term stability is paramount. Rapid maxillary expansion (RME), usually defined as 0.25-0.5 mm of daily expansion, corrects posterior crossbite. A cumulative force of approximately 100 N is applied across the midpalatal suture.[3] Otherwise, slow maxillary expansion (SME), defined as 0.25 mm expansion every second day with 5-20 N of force, can be used.[4] Finally, slow dental maxillary arch expansion (SDE), with pure dentoalveolar effects, can be done using expansion plates with 0.25 mm weekly expansion or one-molar-width activation for quad-helix appliances.

Differences in treatment outcome and stability have been attributed to appliance design and rate of expansion. It has been argued that the arch width added by opening the midpalatal suture can be considered because midpalatal adaptation involves new bone formation, although woven bone may get resorbed by the stretched soft tissue forces. The stability of change added by tooth movement and alveolar bending, on the other hand, is questionable.[5] Most studies, however, focus on relapse as an absolute amount or as a percentage of the amount of expansion that relapses, which is not the clinical outcome of interest following the correction of posterior crossbite. The real question that one should ask is in what proportion of patients does the malocclusion (i.e. the posterior crossbite itself) relapse? It should be kept in mind that overexpansion is usually the rule in posterior crossbite treatment, so data on the amount of transverse relapse may be somewhat misleading as there is fortunately, a physiologic relapse of the overexpanded dental arch towards a normal transversal occlusion. Furthermore, the above-described relapse of overexpansion does not reflect the lack of stability of the corrected posterior crossbite malocclusion.

Previous systematic reviews have investigated several questions related to the long-term effects of maxillary expansion, including the duration of retention following maxillary expansion,[6] transverse intercanine and intermolar width changes following maxillary expansion,[7] gain in arch perimeter[8] and the long-term expansion changes.[9] Srivastava et al[10] reviewed the long-term stability of maxillary expansion concluding that correction performed after the expansion is stable and shows minimal relapse in the long-term, but due to heterogeneity, no meta-analysis was performed.

No meta-analysis, however, has tried to answer to overriding question of what proportion of patients treated for a posterior crossbite show relapse of their malocclusion (i.e. the posterior crossbite itself) in the long term. Looking into this is fundamental since relapse of the malocclusion, not the amount of change in the transverse dimension measured in millimetres (which does not indicate if the crossbite in itself relapsed or not), is the most clinically relevant endpoint.

The primary aim of the present systematic review and meta-analysis was to determine the long-term treatment stability of posterior crossbite correction, treated in the mixed or early permanent dentition of growing children, evaluated at the patient level (relapse of the crossbite itself). The secondary aim was to determine the long-term treatment stability of the amount of expansion (decrease of the initial expansion including overexpansion) in the same patient sample.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

The protocol for this systematic review was registered a priori in PROSPERO (CRD42022348858). Reporting is in accordance with the recommendations outlined by the PRISMA guidelines.[11]

2.2 | Information sources and search

An electronic literature search was performed searching for articles published about the long-term stability of posterior crossbite correction treated in mixed or permanent dentition in growing children, using PubMed, Embase, Cochrane Library and Web of Science. No restrictions were placed on language or publication date. A manual search targeting the reference lists of potentially included studies and relevant review articles, as well as authors known to work in the field, was also conducted. The last search was conducted in January 2023.

2.3 | Eligibility criteria

The eligibility criteria of included studies were determined a priori.

Population: Children and adolescents with posterior crossbite in the mixed or permanent dentition.

Intervention: Correction of posterior crossbite with an orthodontic appliance. All types of maxillary expansion appliances were included in this study, with the purpose of subsequently performing subgroup analyses into those where RME and those where SDE/SME was carried out, provided that enough studies were available to perform these analyses.

Comparison: No formal comparison group since it is assumed that an untreated control group without posterior crossbite will not present a crossbite after follow-up.

Outcome: Relapse or stability in long-term follow-up (percentage of patients that show a relapse of the posterior crossbite; or percentage of the amount of expansion, measured as the maxillary intermolar width, that shows relapse).

Any longitudinal study designs were considered with at least 10 growing patients, treated with maxillary expansion, with long-term follow-up of at least 2 years. Studies presenting no data on long-term follow-up, case reports, review articles, cross-sectional studies, unsupported opinions, non-human studies, treatment performed with surgically-assisted expansion, studies including patients with craniofacial syndromes and/or clefts, medically-compromised or those with temporomandibular disorders were excluded.

2.4 | Study selection and data collection

The literature search and the study selection were carried out by 2 independent reviewers with a third reviewer acting as a mediator. Titles and abstracts of retrieved studies were initially assessed against the eligibility criteria followed by full-text eligibility assessment. Information related to the study samples including sample size, age, gender, and mean age at the start of treatment were recorded. Details about the type of expansion device as well as specifics of the expansion protocol, timing, amount of activation and retention, were retrieved from all included studies. Measurements were accepted from three specific time-points defined as: immediately before expansion (T1); immediately after the completion of expansion (T2); and during long-term follow-up with a minimum follow-up of 2 years post maxillary expansion, irrespective of previous/ongoing retention (T3). Studies excluded based on their full text were recorded along with the reasons.

2.5 | Risk of bias assessment

Based on a risk of bias assessment used in a previous study,[12] the methodological adequacy was assessed with a customized tool that was developed based on various appraisal tools (including the Newcastle-Ottawa scale),[13] using 15 individual questions pertaining to 4 domains: study design, study conduct, statistical analysis, and conclusion, with a maximum score of 25. Studies were graded descriptively as having overall high (score > 20), moderate ($20 \leq$ score ≤ 13) or low (score < 13) methodological adequacy.

2.6 | Summary measures and data synthesis

The primary outcome of this study was to determine the long-term stability of posterior crossbite correction, looking at the percentage of patients who showed relapse of their corrected posterior crossbite at long-term follow-up. Relapse was defined as the presence of a posterior crossbite or an edge-to-edge transverse occlusion at long-term follow-up. The secondary aim was to investigate the percentage of total transverse expansion (including overexpansion) that relapsed. This was calculated as the ratio between the post-treatment relapse of expansion at long-term follow-up (T3-T2) and the total amount of expansion achieved during treatment (T2-T1), measured as maxillary intermolar width. The random-effects meta-analysis model (DerSimonian and Laird inverse variance) was used for all meta-analyses carried out,
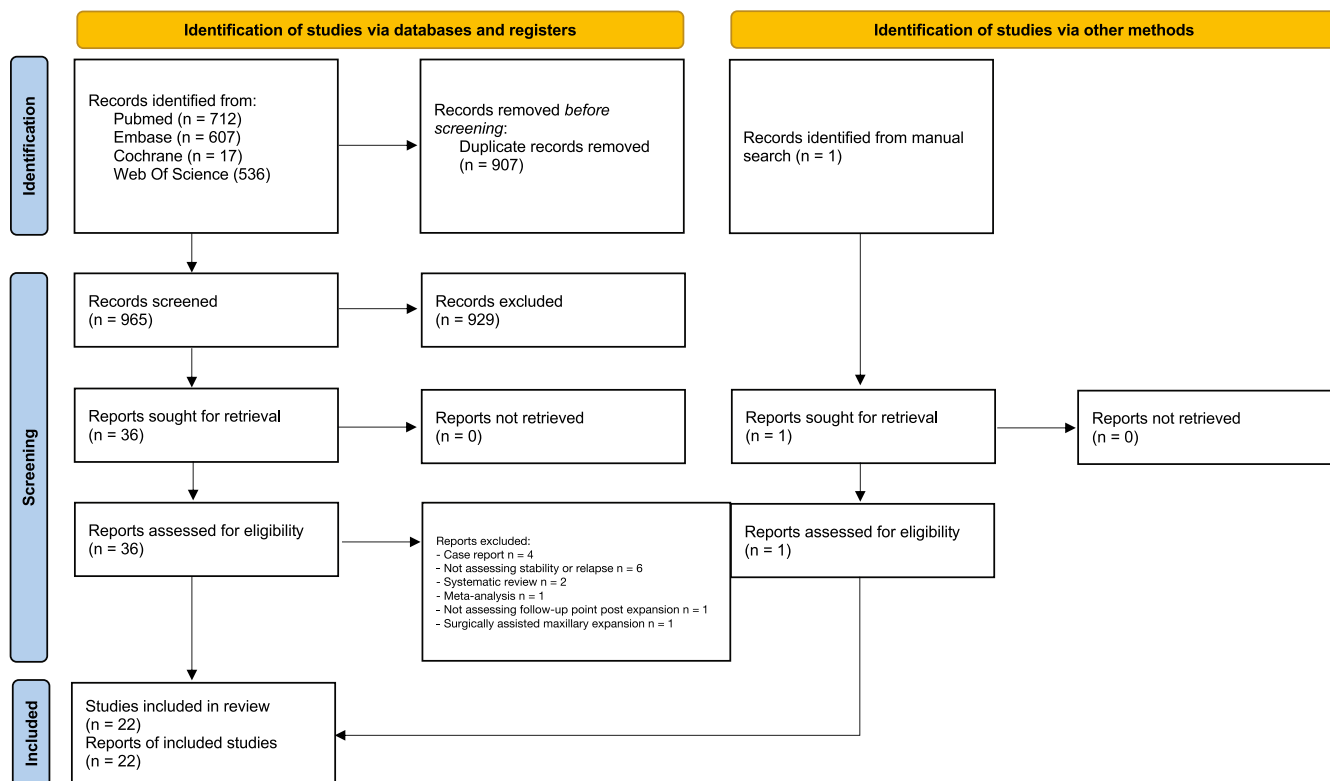

FIGURE 1 Flow diagram for the identification and selection of studies.

TABLE 1 Characteristic of the included studies.

Study	Study design	Treatment groups	Control group	Type of appliance
Atik & Taner, 2017 (18)	Retrospective	Damon after expansion (n=12, 12F/0M, mean age 14.7) Conventional after expansion (n=15, 15F/0M, mean age 14.8)	None	QH
Barzela & Joans, 2007 (24)	Retrospective	SME early treatment (n=25, mean age 7.0±1.3) RME early treatment (n=25, mean age 7.3±1.0) SME late treatment (n=25, mean age 9.8±0.9) RME late treatment (n=25, mean age 10.0±1.8) (sex not specified)	None	Removable plate Bonded RPE
Bazargani et al. 2020 (25)	RCT	TB group (n=26, 13F/13M, mean age 9.3±1.3) TBB group (n=26, 13F/13M, mean age 9.5±1.2)	None	Hyrax-type RPE Hybrid tooth-bone borne
Bjerklin, 2000 (33)	Retrospective	Removable plate (n=19, 9F/10M, mean age 9.2±1.5) QH (n=19, 10F/9M, mean age 9.3±1.4)	n=19, 8F/11M, mean age 8.8±0.5	Removable plate QH
Geran et al. 2006 (36)	Prospective	n=51, 29F/22M, mean age 8.1	n=26, 8F/18M, mean age 8.1	Bonded RPE
Gurel et al. 2010 (37)	Retrospective	n=41, 22F/19M, mean age 13.2±1.3	None	Bonded RPE
Herold, 1989 (20)	Retrospective	RME (n=19, 16F/3M, mean age 12.9±1.3) QH (n=20, 16F/4M, mean age 12.4±1.3) Removable plate (n=11, 5F/6M, mean age 11.2±1.2)	None	Hyrax-type RPE QH Removable plate
Huynh et al. 2009 (21)	Retrospective	Haas (n=74, 51F/23M, mean age 8.1±1.1) Hyrax (n=41, 33F/26M, mean age 7.8±1.1) QH (n=45, 26F/15M, mean age 8.3±1.0)	None	Haas-type RPE Hyrax-type RPE QH
Iseri & Ozsoy, 2003 (38)	Retrospective	n=20, 19F/1M, mean age 14.6±0.4	n=20 19F/1M, mean age 13.8±0.3	Bonded RPE
Kim et al. 2019 (26)	Retrospective	n=67, 53F/14M, mean age 12.3±2.5	None	Haas-type RPE
Lima et al. 2005 (27)	Retrospective	n=30, 18F/12M, mean age 8.2	None	Haas-type RPE
Linder-Aronson & Lindgren, 2016 (40)	Retrospective	n=23, 16F/7M, mean age 14.4	None	Hyrax-type RPE
McNamara et al. 2003 (28)	Prospective	n=112, 61F/51M, mean age 12.2±1.4	n=41, 17F/24M, mean age 11.6±1	Haas-type RPE
Mehta et al. 2021 (35)	Retrospective	Bone-borne (n=20, mean age 13.7±1.7) Hyrax-type RPE (n=21, mean age 13.9±1.1) (sex not specified)	n=19, mean age 13.3±1.5 (sex not specified)	Bone-borne Hyrax-type RPE
Memikoglu & Iseri, 1999 (39)	Retrospective	n=14, 11F/3M, mean age 12.8±1.0	None	Bonded RPE

Intervention	Type of expansion	Fixed appliance	Retention	Type of retention	Follow-up points
Expansion until lingual cusps of the maxilla first molars in contact with buccal cups of mandibular first molars	Slow	Yes	QH until SS archwires	Same appliance used as retention	T1: preoperatively T2: after treatment T3: 3 y
SME 0.2 mm/wk RME 0.4 mm/d	Slow Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: end of active treatment T4: 2 y
0.5 mm/d. Until palatal cusps of the maxillary first molars contacted the buccal cusps of the mandibular first molars	Rapid Rapid	No	6 mo	Same appliance used as retention	T0: preoperatively T1: after expansion T2: 1-year post-treatment T3: 5 y
0.25-0.50 mm/wk 3-5 mm expansion	Slow Slow	No	3-5 mo	Same appliance used as retention	T1: preoperatively T2: after treatment T3: 5.5 y
0.25 mm/d. Until a buccal CB was approached	Rapid	Yes	5 mo	Same appliance used as retention	T1: preoperatively T2: post-treatment T3: ≥5 y
0.5 mm/d at first. 0.25 mm/d after suture mobilized. Expansion stopped once palatal cusps of the upper posterior teeth came into contact with the lingual cusps of the lower posterior teeth	Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: after treatment T4: ≥ 5 y
Not specified	Rapid Slow Slow	No	Not specified	Not specified	T1: preoperatively T2: after expansion T3: 4 y
Haas and Hyrax 0.25 mm/every 2 d QH 1 mol/L width activation. Until the crossbite was mildly overcorrected so the lingual mandibular buccal cusp contacted the buccal maxillary lingual cusp	Slow	No	6 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: ≥2 y
0.4 mm/d during 5-7 d. Then slow expansion	Rapid + slow	No	4 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: after retention T4: ≥2 y after expansion
0.5 mm/d. Until the expansion screw reached 11-14 mm	Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: 13 y later
0.5 mm/d. Screw opening 8-11 mm. Overcorrection done but amount not specified	Rapid	No	5 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: 5 y
Not specified. Mean expansion period 2 mo	Rapid	No	1.7 y	Not specified	T1: preoperatively T2: after expansion T3: after retention T4: 5 y
0.5 mm/d. Until the expansion screw reached 10.5 mm	Rapid	Yes	2 mo	Same appliance used as retention	T1: preoperatively T2: after treatment T3: 8 y
2 turns/d	Rapid Rapid	Yes	Not specified	Not specified	T1: preoperatively T2: after expansion T3: 2.9 y
0.40 mm/d	Rapid	Yes	6 mo	Same appliance used as retention	T1: preoperatively T2: after expansion T3: end of treatment

(Continues)

TABLE 1 (Continued)

Study	Study design	Treatment groups	Control group	Type of appliance
Mew, 1983 (25)	Retrospective	n=25, 15F/10M, mean age 8.3±1.2	None	Removable plate
Micheletti et al. 2016 (29)	Retrospective	n=10, 3F/7M, mean age 8.3±1.2	n=21, similar age to experimental group (sex not specified)	Haas-type RPE
Mohan et al. 2016 (30)	Retrospective	Mixed dentition (n=24, age>18y) Permanente dentition (n=24, age>18y) (sex not specified)	None	Haas-type RPE
Moussa et al. 1995 (31)	Retrospective	n=55, 39F/16M, mean age 12.1±2.6	None	Haas-type RPE
Petren et al. 2011 (22)	RCT	QH (n=20, 11F/9M, mean age 9.0±1.2) Expansion plate (n=15, 0F/5M, mean age 8.5±1.0)	n=20, 9F/11M, mean age 8.8±0.5	QH Removable plate
Pinheiro et al. 2014 (32)	Retrospective	RME (n=30, 9F/21M, mean age 12.7±21.2) SME (n=30, 8F/22M, mean age 13.7±5.2)	n=30, 17F/13M, mean age 13.0±1.5	Haas-type RPE
Tsarapatsani et al. 1999 (23)	Retrospective	n=11, 18F/11M, mean age 8-12	None	QH

Abbreviations: F, female; M, male; QH, quadhelix; RCT, randomized controlled trial; RME, rapid maxillary expansion; RPE, papid palatal expander; SME, slow maxillary expansion; SS, stainless steel; TB, tooth borne; TBB, tooth-bone borne.

and heterogeneity was assessed using the I^2 statistic as well as Cochran's Q test. The overall certainty of evidence (confidence in effect estimates) for both the primary and second outcome, was rated using the GRADE approach.[14]

Subsequently, subgroup analyses were planned, where possible, whereby the data were divided into type of appliance (those where RME and those where SDE/SME was performed), previous or on-going retention, sex, age groups, dentition, or crossbite severity (unilateral or bilateral). Finally, however, based on the available data, only subgroup analysis based on the type of appliance was possible. Sensitivity analyses were also planned, excluding studies with a high risk of bias to see whether a significant change in the prevalence estimates would be apparent, or excluding studies with a non-habitual expansion protocol. All statistical analyses were carried out using MetaXL version 2.0 (epigear.com).

3 | RESULTS

3.1 | Study selection

The initial literature search strategy yielded 1872 results. After removing duplicates (n=907), the remaining 965 references were screened for relevance. A total of 929 articles were excluded,

according to the eligibility criteria, based on their title and abstract. Subsequently, the full texts of 36 articles were retrieved and 15 articles were afterwards excluded as they failed to meet eligibility criteria (Table S1). One additional study was identified from the manual search. A final sample of 22 studies was included in the qualitative and quantitative synthesis (Figure 1; Table 1).

3.2 | Study characteristics

From the 22 longitudinal studies included, 2 were randomized controlled trials, 2 were prospective controlled clinical trials and the remaining were retrospective clinical trials. Inclusion criteria within each individual study varied; however, all patients had maxillary expansion. The combined samples from the included studies represented a total of 1076 treated patients. The expansion appliance used in the studies included quad-helix appliances (6 studies),[15–20] removable plates (5 studies),[16,17,19,21,22] Haas-type RME (8 studies),[18,23–29] Hyrax-type RME (5 studies),[17,18,30–32] bonded RME (5 studies),[21,33–36] hybrid tooth-bone-borne expander (1 study)[33] and bone-borne expander (1 study).[30] The majority of studies included patients with both unilateral and bilateral crossbites or did not specify the extent of the pre-treatment crossbite, which did not allow an evaluation of crossbite severity.

Intervention	Type of expansion	Fixed appliance	Retention	Type of retention	Follow-up points
1 mm/wk. Overexpansion 2-4 mm	Slow	Some	4 y	Not specified	T1: preoperatively T2: after expansion T3: 4 y
0.5 mm/d. Expansion completed when the palatal cusps of the maxillary first molars touched the buccal cusps of the mandibular first molar	Rapid	Yes	3 mo	Same appliance used as retention	T0: preoperatively T1: 3 mo after expansion T2: 1 y after expansion T3: 3 y after expansion
Not specified	Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after treatment T3: 11 y after treatment
0.5 mm/d	Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after treatment T3: after retention T4: 18 y
QH: activation 10 mm before placement and reactivated every 6 wk if necessary. No overcorrection Plate: 0.2 mm/wk. No overcorrection	Slow Slow	No	6 mo	Same appliance used as retention	T0: preoperatively T1: after treatment T2: 3 y
0.5 mm/d. 3 mm overcorrection	Rapid	Yes	3 mo	Same appliance used as retention	T1: preoperatively T2: after treatment T3: 5 y
Not specified	Slow	No	Not specified	Not specified	T1: preoperatively T2: after treatment T3: 8-12 y after

The duration of active expansion varied between studies, representing the varied needs of individual patients. While the expansion protocol was well-defined in most studies, it was not reported in 2 studies. Retention protocols varied, with the most common practice being to keep the expander in place passively for a defined period. Two studies did not provide adequate information with regard to their retention protocol. Maxillary intermolar distance measured was evaluated at the central fossa and gingival crest. All studies recorded baseline maxillary intermolar distances prior to expansion, after the expansion and after long-term follow-up.

3.3 | Risk of bias in individual studies

The methodological adequacy of included studies was found to be high for one (score > 20), moderate for 18 (20 ≤ score ≤ 13) and low for 3 studies (score < 13) (Table 2). The study objectives, main outcomes, patient characteristics and interventions were clearly described by all included studies. However, due to the nature of the intervention, blinding of the participants was not possible in most studies. Four studies attempted to blind the outcome assessors.

3.4 | Results of individuals studies and data synthesis

When analysing relapse of the crossbite, meta-analysis results showed that 19.5% (95% CI: 15%; 25%) of patients present with relapse at the long-term follow-up (Figure 2A). This result, based on 6 studies and 409 patients, showed insignificant heterogeneity (Cochran's $Q = 7.9$; $I^2 = 37\%$; $P = .16$). When analysing the results at the expansion level, based on 21 studies and 1065 patients, meta-analysis results showed that 19.3% of the expansion relapsed (95% CI: 13%; 27%) (Figure 3A), with significant heterogeneity (Cochran's $Q = 232.6$; $I^2 = 91\%$; $P < .001$). Sensitivity analysis was performed, excluding studies using skeletal anchorage, or excluding studies with a high risk of bias, without this changing prevalence estimates significantly. Following the assessment of the certainty of evidence with the GRADE approach, it can be suggested that the quality of evidence for these prevalence estimates is "low-moderate", due to the nature of the included studies and methodological limitations.

When subgroup analysis was performed at the crossbite level, with data divided into those where RME and those where SDE/SME was performed, results showed that for RME 16.7% (95% CI: 7%; 29%) of patients present with relapse at long-term follow-up

TABLE 2 Risk of bias assessment of the included studies.

	Randomization	Sample described	Selection criteria	Sample size	Controls used	Follow-up	Dropouts	Intervention protocol
Atik & Taner, 2017	0	2	2	2	0	2	1	2
Barzela & Joans, 2007	0	1	2	2	0	2	1	2
Bazargani et al, 2020	1	2	2	2	0	2	1	2
Bjerklin, 2000	0	2	2	2	1	2	1	2
Geran et al, 2006	0	2	2	2	1	2	1	2
Gurel et al, 2010	0	2	2	2	0	2	0	2
Herold, 1989	0	2	1	2	0	2	0	0
Huynh et al. 2009	0	2	2	2	0	2	1	2
Iseri & Ozsoy, 2003	0	2	1	2	1	2	0	2
Kim et al 2019	0	2	1	2	0	2	0	2
Lima et al, 2005	0	2	2	2	0	2	1	2
Linder-Aronson, 2016	0	2	2	1	0	2	1	0
McNamara et al, 2003	0	2	2	2	1	2	1	2
Memik& Iseri, 1999	0	2	2	1	0	2	1	2
Mehta et al, 2021	0	1	2	2	1	2	0	1
Mew, 1983	0	1	2	2	1	2	0	1
Micheletti et al, 2016	0	2	2	1	1	2	0	2
Mohan et al, 2016	0	2	1	2	0	2	0	0
Moussa et al, 1995	0	2	2	2	0	2	0	2
Petren et al, 2011	1	2	2	2	1	2	1	2
Pinheiro et al, 2014	0	2	2	2	1	2	1	2
Tsaraptsani et al, 1999	0	2	2	2	0	1	1	0

(Figure 2B), while for SDE/SME 20.7% (95% CI: 11%; 32%) of patients present with relapse at long-term follow-up (Figure 2C).

When subgroup analysis was performed at the expansion level, meta-analysis results showed that for RME 14.5% (95% CI: 7%; 24%) of the expansion performed relapses at long-term follow-up (Figure 3B), while for SDE/SME 25.9% (95% CI: 18%; 35%) of the expansion performed relapses at long-term follow-up (Figure 3C).

4 | DISCUSSION

The present results show that approximately 1 in 5 patients show relapse of their posterior crossbite correction at long-term follow-up. When looking at relapse at the expansion level, approximately one-fifth of total expansion performed relapses in the long term, which is roughly equivalent to the amount of overexpansion habitually performed.

Subgroup analysis dividing patients between those receiving RME and those receiving SDE/SME showed that patients receiving SDE/SME have a higher long-term relapse. We also wished to perform subgroup analysis based on dentition (mixed vs. permanent dentition), age at which expansion was carried out, and unilateral versus bilateral crossbite correction but data were not sufficient to do so.

An interesting question leading on from these results is which patients are more prone to relapse. Factors such as patient age,[31]

expansion rate,[37,38] appliance design,[5] length of retention,[39] response of the midpalatal suture and surrounding structures[37,40] and soft-tissue adaptation to the new positions[41] have been put forward and discussed. Included studies were perused to identify factors that were mentioned that have a potential impact on the relapse potential of treated posterior crossbites. These factors were collated and presented in Table 3.

Some authors report growth as a cofactor for relapse, considering the amount and the direction of growth during the post-retention period, especially in cases with a Class III or asymmetric growth pattern, to be at least partially responsible for the occlusal changes.[42,43] Baccetti et al[44] showed that RME treatment during early development stages gives more skeletal expansion and more stable long-term results. Wertz and Dreskin[45] showed that maxillary skeletal expansion underwent no relapse in younger patients, whereas older patients lost most of the width increase achieved through expansion.

Regarding the design of the appliance, recent reports show no difference between Haas-type expanders and other appliances.[18] Hicks[4] reported that the amount of relapse is related to the retention procedure after expansion, stating that if the expander was removed immediately after active expansion, a relapse could be as much as 45% of the expansion achieved. Fixed retention for 2-3 months allowed 10%-23% of relapse, whereas removable retention allowed 22%-25% of relapse. In this regard, Storey[46] reported that after RME a 3- to 6-month retention period is recommended.

Measurement described	Assessor blindind	Reability /error testing	Appropriate statistics	Confounders analysed	Presentation of data	Conclusions	TOTAL	Methodological adequacy
2	0	1	1	0	2	0	17	Moderate
2	0	1	1	0	0	1	15	Moderate
2	1	1	1	0	2	1	20	Moderate
2	2	0	1	0	2	1	19	Moderate
2	0	1	1	0	2	1	19	Moderate
2	0	0	1	0	1	1	15	Moderate
0	0	1	1	0	2	1	12	Low
2	1	1	1	0	2	1	19	Moderate
2	0	1	1	0	2	1	17	Moderate
2	0	1	1	0	2	1	16	Moderate
2	0	1	1	0	2	1	18	Moderate
0	0	0	0	0	0	1	9	Low
2	0	1	1	0	2	1	19	Moderate
2	0	1	1	0	0	0	14	Moderate
2	0	1	1	0	1	1	15	Moderate
2	0	1	1	0	1	1	15	Moderate
2	0	1	1	0	1	1	16	Moderate
2	0	1	1	0	2	1	14	Moderate
2	0	1	1	0	2	1	17	Moderate
2	1	1	1	0	2	1	21	High
0	1	1	1	0	2	1	18	Moderate
0	0	0	1	0	1	1	11	Low

The main findings of our meta-analysis were that 19.5% of patients show a relapse of their crossbite after long-term follow-up and that the average amount of relapse in all patients following maxillary expansion was 19.3% of the expansion accomplished, which at a first glance seems to support the opinion that overcorrection may be necessary to compensate for this amount of relapse. However, whether overcorrection is necessary remains an unanswered question since it may be interpreted that relapse is a physiological process to counterbalance the overexpansion performed that per se, does not create a stable occlusion. In an older study investigating relapse following maxillary expansion, it was argued that it would be of little value to measure relapse of the overexpansion because it is difficult to distinguish between relapse of the overexpansion and undesirable relapse.[22] As the objective of an expansion treatment is to resolve the crossbite (transverse discrepancy), the out-of-retention widening should be sufficient to accommodate the lower arch without crossbite. It is unclear however what role the overexpansion and its quantity can have on relapse.

These results are in accordance with other studies previously published. Gurel et al[34] found that the relapse rate was 17% over a 5-year follow-up period although the final maxillary intermolar width was 4.6 mm larger than its pretreatment dimension and closely approximated its posttreatment dimension. Likewise, Geran et al[33] found that the increase in maxillary intermolar width was 4.2 mm

and the relapse rate was 18% over a 5-year follow-up period. Other studies found a greater percentage of relapse. Linder-Aronson and Lindgren[30] reported a net increase of 2.1 mm and a relapse rate of 62% in subjects treated with the Hyrax appliance. Kurol et al[47] found that less than 50% of their treatments with removable expansion plates were successful.

It has been suggested that early correction of the crossbite in the deciduous dentition has a positive influence on further maxillary development and may prevent long-term negative consequences on growth and development of the teeth and jaws leading to craniofacial asymmetry.[48] However, relapse may sometimes be expected, which puts the benefits of such early treatments in question. Moreover, it has been found that up to three-quarters of posterior crossbites in the deciduous dentition are corrected spontaneously as the child develops into the mixed dentition.[49] Focusing on identifying which patients are more prone to asymmetric growth, and those more prone to relapse following maxillary expansion is paramount. Hopefully, more data on the long-term stability of crossbite correction in different subgroups of patients will help in this regard.

The foremost strength of this systematic review and meta-analysis is the clinically relevant question analysed, namely the prevalence of relapse of the malocclusion (i.e. posterior crossbite), rather than looking solely at the millimetric relapse in the transverse dimension, which in itself does not hold much clinical importance
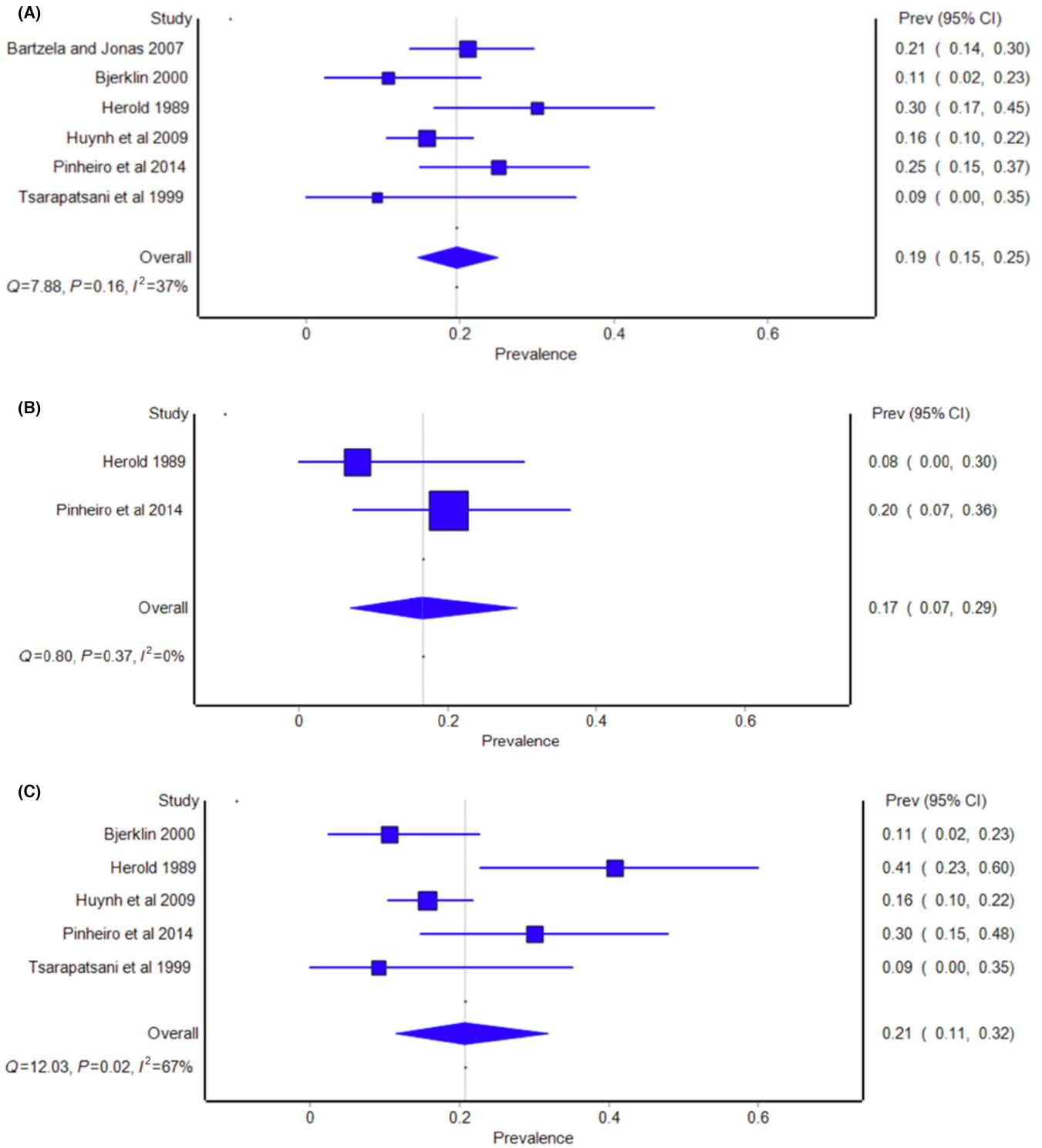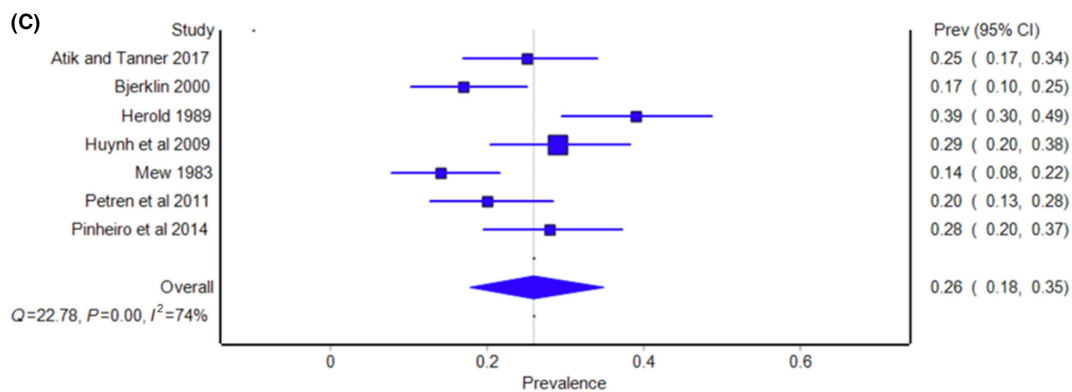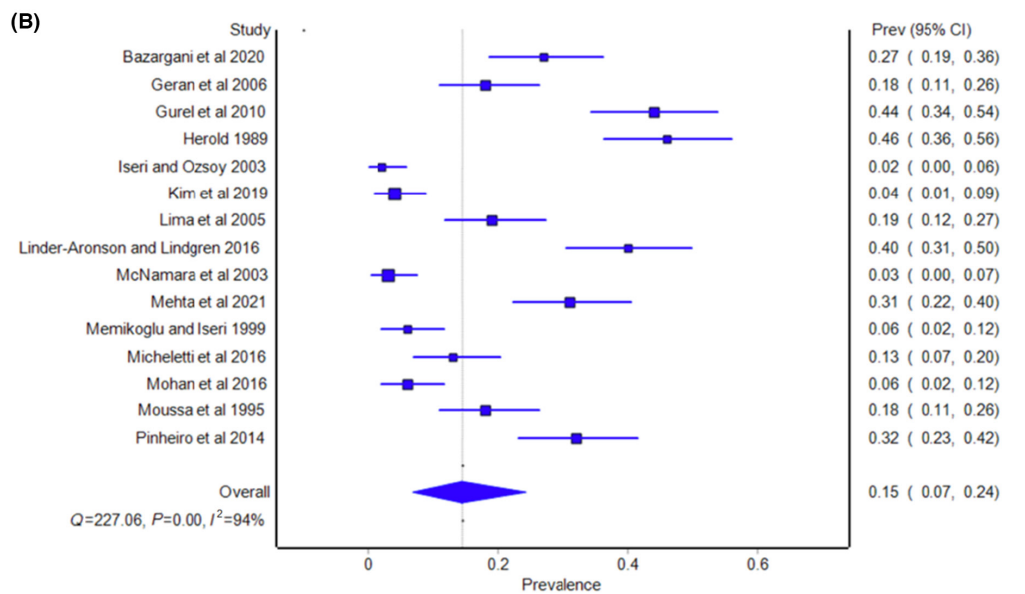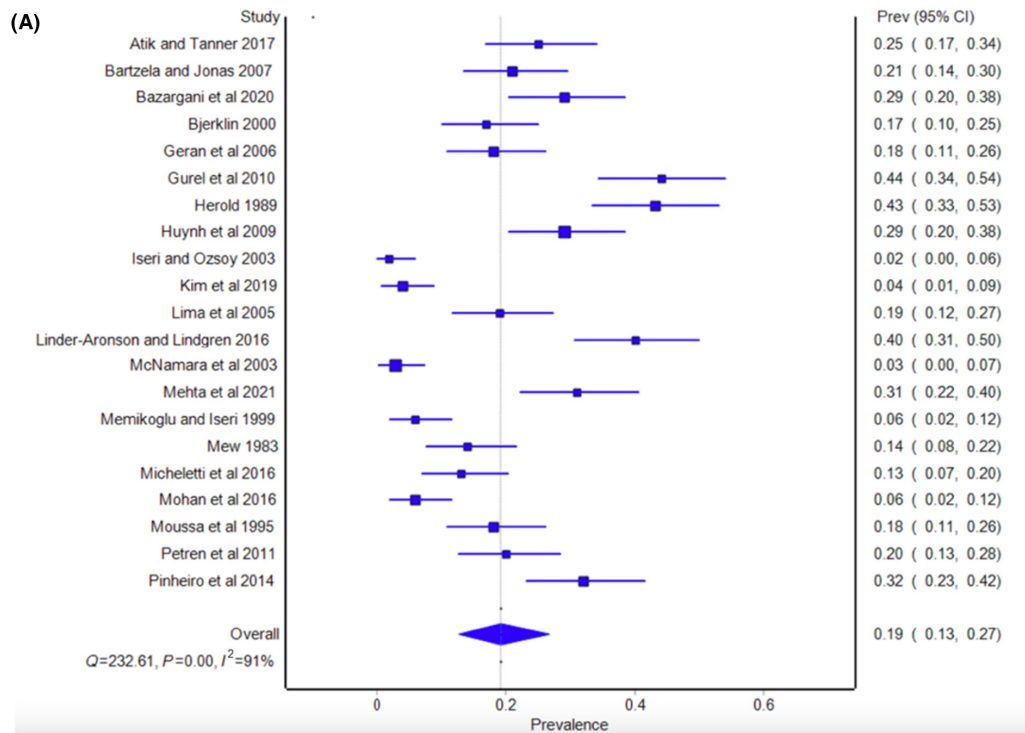
FIGURE 2 A, Forest plot showing the proportion of patients with relapse of their posterior crossbite following maxillary expansion, at long-term follow-up, using a random-effects meta-analysis (based on a cumulative sample of 409 patients). B, Forest plot showing the proportion of patients with relapse of their posterior crossbite following rapid maxillary expansion, at long-term follow-up, using a random-effects meta-analysis. C, Forest plot showing the proportion of patients with relapse of their posterior crossbite following slow dental/maxillary expansion, at long-term follow-up, using a random-effects meta-analysis.

FIGURE 3 A, Forest plot showing the proportion of transverse relapse after maxillary expansion (proportion of total expansion, including overexpansion), using a random-effects meta-analysis (based on a cumulative sample of 1065 patients). B, Forest plot showing the proportion of transverse relapse after rapid maxillary expansion (proportion of total expansion, including overexpansion), using a random-effects meta-analysis. C, Forest plot showing the proportion of transverse relapse after slow dental/maxillary expansion (proportion of total expansion, including overexpansion), using a random-effects meta-analysis.

(A)

Study	Prev (95% CI)
Atik and Tanner 2017	0.25 (0.17, 0.34)
Bartzela and Jonas 2007	0.21 (0.14, 0.30)
Bazargani et al 2020	0.29 (0.20, 0.38)
Bjerklin 2000	0.17 (0.10, 0.25)
Geran et al 2006	0.18 (0.11, 0.26)
Gurel et al 2010	0.44 (0.34, 0.54)
Herold 1989	0.43 (0.33, 0.53)
Huynh et al 2009	0.29 (0.20, 0.38)
Iseri and Ozsoy 2003	0.02 (0.00, 0.06)
Kim et al 2019	0.04 (0.01, 0.09)
Lima et al 2005	0.19 (0.12, 0.27)
Linder-Aronson and Lindgren 2016	0.40 (0.31, 0.50)
McNamara et al 2003	0.03 (0.00, 0.07)
Mehta et al 2021	0.31 (0.22, 0.40)
Memikoglu and Iseri 1999	0.06 (0.02, 0.12)
Mew 1983	0.14 (0.08, 0.22)
Micheletti et al 2016	0.13 (0.07, 0.20)
Mohan et al 2016	0.06 (0.02, 0.12)
Moussa et al 1995	0.18 (0.11, 0.26)
Petren et al 2011	0.20 (0.13, 0.28)
Pinheiro et al 2014	0.32 (0.23, 0.42)
Overall	**0.19 (0.13, 0.27)**

$Q=232.61$, $P=0.00$, $I^2=91\%$

Prevalence

(B)

Study	Prev (95% CI)
Bazargani et al 2020	0.27 (0.19, 0.36)
Geran et al 2006	0.18 (0.11, 0.26)
Gurel et al 2010	0.44 (0.34, 0.54)
Herold 1989	0.46 (0.36, 0.56)
Iseri and Ozsoy 2003	0.02 (0.00, 0.06)
Kim et al 2019	0.04 (0.01, 0.09)
Lima et al 2005	0.19 (0.12, 0.27)
Linder-Aronson and Lindgren 2016	0.40 (0.31, 0.50)
McNamara et al 2003	0.03 (0.00, 0.07)
Mehta et al 2021	0.31 (0.22, 0.40)
Memikoglu and Iseri 1999	0.06 (0.02, 0.12)
Micheletti et al 2016	0.13 (0.07, 0.20)
Mohan et al 2016	0.06 (0.02, 0.12)
Moussa et al 1995	0.18 (0.11, 0.26)
Pinheiro et al 2014	0.32 (0.23, 0.42)
Overall	**0.15 (0.07, 0.24)**

$Q=227.06$, $P=0.00$, $I^2=94\%$

Prevalence

(C)

Study	Prev (95% CI)
Atik and Tanner 2017	0.25 (0.17, 0.34)
Bjerklin 2000	0.17 (0.10, 0.25)
Herold 1989	0.39 (0.30, 0.49)
Huynh et al 2009	0.29 (0.20, 0.38)
Mew 1983	0.14 (0.08, 0.22)
Petren et al 2011	0.20 (0.13, 0.28)
Pinheiro et al 2014	0.28 (0.20, 0.37)
Overall	**0.26 (0.18, 0.35)**

$Q=22.78$, $P=0.00$, $I^2=74\%$

Prevalence

TABLE 3 Factors reported to be potentially associated with relapse of posterior crossbite correction.

	Factors
Patient-related	Sex
	Age
	Ethnicity
	Breathing problems
	Trauma
	Growth
	Extent of crossbite (uni- or bilateral)
Treatment-related	Rate of expansion
	Appliance design
	Compliance
	Dental extractions
	Overexpansion
Retention-related	Retention protocol
	Compliance
	Length of follow-up
	Soft tissues adaptation
	Response of midpalatal suture

provided that the posterior crossbite correction remains stable. The main shortcoming of this study is the limited number of existing studies, most of which are non-randomized studies with methodological limitations and deficiencies in their quality. In addition, studies included heterogeneous groups of patients with regard to age, dentition, crossbite extent (unilateral and bilateral), and treatment and retention protocols adhered to. Nevertheless, when performing sensitivity analyses excluding studies with a high risk of bias, the prevalence estimates did not change to a significant extent.

The prevalence estimates obtained from the meta-analyses were considered to be of low-moderate certainty, using the GRADE approach, given the design and methodological inadequacies of the included studies. It might be valuable, moving forward, to assess relapse potential following posterior crossbite correction based on sex, age, dentition, crossbite severity and anteroposterior dental and skeletal relationships, quantifying the differences, if any, between these patient subgroups. Long-term prospective randomized clinical trials are needed to reinforce our knowledge in this field, while it is important to define relapse of the initial malocclusion (posterior crossbite) as opposed to a decrease of the overexpanded maxillary arch width.

5 | CONCLUSIONS

Evidence from existing clinical studies indicates that the long-term stability of posterior crossbite correction in the mixed and permanent dentition is favourable, with an appraised low-moderate certainty of evidence. Based on existing studies:

- Roughly one in five growing children who undergo posterior crossbite correction with maxillary expansion show relapse of their crossbite in the long term.
- On average, 19% of the measured maxillary expansion achieved during posterior crossbite correction relapses in the long term, which corresponds roughly to the amount of overexpansion habitually prescribed.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The datasets used and/or analysed for the current study will be made available from the corresponding author upon reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.