Systematic Review Article

Rapid maxillary expansion vs slow maxillary expansion in patients with cleft lip and/or palate: a systematic review and meta-analysis

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ABSTRACT

Objectives: To compare the dentoalveolar outcomes of slow maxillary expansion (SME) and rapid maxillary expansion (RME) used for maxillary expansion before secondary alveolar bone grafting in patients with cleft lip and/or palate (CL/P). Secondarily, the advantages and disadvantages of SME vs RME were reviewed.

Materials and Methods: A systematic search was conducted up to November 2021, including Medline (via PubMed), Embase (via Ovid), Web of Science, Cochrane Central, and Google Scholar. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed. Risk-of-bias assessment was performed using the Risk of Bias (RoB 2.0) and Risk Of Bias In Non-randomized Studies of Interventions (ROBINS I) tool. Overall quality was assessed using the Grading of Recommendations Assessment, Development, and Evaluation tool.

Results: Of 4007 records, five studies met the inclusion criteria. The randomized control trial (RCT) had a low risk of bias, the non-RCTs presented with a moderate risk of bias. Arch width and perimeter increased significantly with both SME and RME treatments. No difference in the increase in palatal depth was found. The meta-analysis showed a greater anterior-to-posterior expansion ratio for the Quad Helix (QH) appliance. The results for dental tipping were not conclusive.

Conclusions: SME and RME promote equal posterior expansion in cleft patients. The anterior differential expansion is greater with SME (QH appliance). No clear evidence exists concerning the amount of dental adverse effects of SME and RME in cleft patients. (*Angle Orthod.* 2022;93:95–103.)

KEY WORDS: Expansion; Cleft lip and palate

INTRODUCTION

Orofacial clefting is the most common craniofacial birth defect in humans with an average prevalence of 1.7/1000 births worldwide with ethnic and geographic variations. Many factors contribute to cleft conditions, including heredity, drug exposure, prenatal nutrition, and environmental factors.[1] Cleft lip and/or palate (CL/P) patients undergo several surgical procedures from birth up to adulthood, starting with the correction of the cleft lip and palate after birth to restore basic function and esthetics. When the cleft also compromises alveolar integrity, a bone grafting procedure needs to be performed. Alveolar bone grafting procedures can be defined by age or by dental development.[2] When referring to age, terminology such as early, middle, and late alveolar bone grafting are used. However, there is no consensus in the literature on the real ages corresponding to these categories.[3]

Using dental development as a guide, primary, secondary, and tertiary grafting are used. Primary grafting means that the procedure is performed after lip

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Table 1. PICOS Question[a]

	Inclusion Criteria	Exclusion Criteria
P	Patients with UCL/P or BCL/P needing expansion before SABG	CL/P patients without the need for expansion Previous SABG/expansion
I	SME type expanders	Experimental expansion devices
C	RME type expanders	Experimental type expanders; appliances with a slow expansion protocol
O	Transversal measurements on study casts, digital scans, or CBCT images	Cephalometric measurements
S	All prospective or retrospective cohort studies and RCTs	Case reports, case series, systematic reviews

[a] CBCT indicates cone beam computed tomography; RCT, randomized control trial.

repair but before palatal closure. Secondary bone grafting is performed during the mixed dentition stage. When the adult dentition has completely erupted, tertiary bone grafting is possible.[3] Today, no consensus has been reached about the ideal timing for bone grafting. A review performed in 2018 concluded that no sufficient evidence exists toward the determination of specific timing for alveolar grafting and that success rates are high for all timing options.[3] Recent publications indicate a preference for alveolar bone grafting before the eruption of maxillary lateral incisors, when the patient is between 4 and 7 years old. In that way, not only the maxillary canine but also the lateral incisor is given the opportunity to erupt through the grafted section, restoring not only the integrity of the alveolar maxillary base but also creating an eruption path for the canine.[4] Currently, the most used procedure is secondary alveolar bone grafting (SABG) performed around the age of 9, just before the eruption of the canine.[5]

In unilateral CL/P (UCL/P) and bilateral CL/P patients (BCL/P), collapse of the maxillary arch is observed with an inward displacement of the lesser or affected segment. Often the posterior dimension is unaffected, and the largest discrepancy is found anteriorly.[6,7] Correction of the transverse uni- or bilateral discrepancy not only provides the basis for a proper arch form after bone grafting but also facilitates easy surgical access by enlarging the cleft defect, thereby resulting in higher success rates of the surgical bone grafting procedure.[8]

Expansion before SABG is often performed by the orthodontist. A plethora of appliances can be used. The Quad Helix (QH) appliance, the Haas expander, the Hyrax expander, or some experimental designs with anteriorly placed expansion screws promoting selective expansion (also called fan-type expanders) have been described. The design of the appliance is one factor to consider, but also the speed at which the expansion is achieved plays a role. Some authors claim that rapid maxillary expansion (RME) has advantages when compared with slow maxillary expansion (SME). However, these conclusions are mostly based on research in noncleft patients, indicating less bone formation in SME when compared with RME. The higher forces in RME resulted in more midpalatal suture opening but also showed some dental adverse effects.[9,10]

This is the first review investigating the effects of SME and RME in patients with CL/P. Therefore, the aim of this systematic review and meta-analysis was to compare the dentoalveolar outcomes of SME and RME used for maxillary expansion before SABG in patients with CL/P. Secondarily, the advantages and disadvantages of SME vs RME were reviewed.

MATERIALS AND METHODS

Protocol and Registration

The protocol of this systematic review and meta-analysis was registered in advance at the International Prospective Register of Systematic Reviews (PROSPERO) database (reference number CRD42022302844). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to develop the protocol, and the review was conducted according to the principles of the Cochrane Handbook of Systematic reviews.[11]

Eligibility Criteria

According to the PRISMA system, the Population, Intervention, Comparison, Outcome and Study Design (PICOS) question was formulated (Table 1). All RCTs or non-RCTs comparing SME and RME appliances in UCL/P or BCL/P patients before SABG were considered eligible. Studies investigating patients without a maxillary transverse discrepancy were excluded.

Information Sources and Search Strategy

A broad search strategy was applied because of the very specific nature of the research question (expansion in patients with CL/P). No filters were applied, and the full search strategy can be found in Supplemental Table 1. A systematic electronic search was conducted up to November 2021 in accordance with Bramer et

al.,[12] including the following databases: Medline (via PubMed), Embase (via Ovid), Web of Science, the Cochrane Central Library, and Google scholar. To account for gray literature, the Open Grey database was searched. Clinicaltrials.gov and the European Union Clinical Trial Register were searched as well, revealing no extra publications. A manual search in the references of the included publications was performed. No restrictions on year or status of publications and languages were applied.

Study Selection

Following the search, duplicates were removed using Endnote software (Clarivate Analytics, London, UK), and subgroups were defined in the software package to aid in the selection process. The selection of the articles was performed in two stages. First, all retrieved articles were screened on title and abstract independently by two authors (Dr Luyten and Dr Christiaens). Subsequently, the full eligibility criteria were applied to the full text of the included articles by the same two authors. In case of disagreement, a third author (Van Overberghe) was consulted. Similar studies were grouped by comparing their characteristics using the PICO model.

Data Collection and Data Items

Two reviewers independently collected the primary data from the included articles. The following items were extracted: authors, year of publication, study design, study setting, number of participants, patient characteristics, age, intervention, appliance design, appliance management, data collection, outcomes, methods of outcome evaluation, and results. After data extraction, data were synthesized by two authors and converted into a format useful for comparison.

Risk of Bias Within Studies

According to the principles of the Cochrane handbook, possible bias in the nonrandomized trials was assessed using the ROBINS-I tool and in the RCTs using the RoB 2.0 tool.[11] All studies were evaluated independently by two authors (Dr Luyten and Van Overberghe). In case of disagreement, a third author (Dr Christiaens) was consulted to act as a decision maker.

Risk of Bias Across Studies and Additional Analysis

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was used to detect publication bias and to obtain the overall quality grade for the level of evidence. I^2 statistics were used to assess the heterogeneity of the meta-analysis, with the significance level set at .05. Funnel plot representation of the meta-analysis was not performed because of its lack of evidence in a sample of less than 10 studies.[11] Sensitivity analysis was performed by analyzing the influence of a single study on the overall effect.

RESULTS

Study Selection

The initial search yielded 4007 records. After screening on title and abstract, only 208 records remained. Finally, only five studies were included in this review after application of the eligibility criteria. The PRISMA flowchart is presented in Figure 1.

Study Characteristics

An overview of the included studies and their characteristics is shown in Table 2. One RCT and four cohort studies, representing a total of 214 patients with CL/P who were treated with SME or RME before SABG, were included. All included patients had a transverse maxillary deficiency and had no history of craniofacial syndromes. Two studies only included BCLP patients[13,14]; all other studies consisted of both UCLP and BCLP patients. The study by Dalessandri et al. was the only study to also include cleft lip and soft tissue cleft, but failed to describe what this entailed.[15] The mean patient age ranged between 6 and 13 years old. Only the study by Vasant et al. defined age based on the dental developmental stage (mixed dentition).[16]

SME in all studies was performed using the QH appliance. RME was performed with the Hyrax appliance. One study also used an experimental differential opening expander as a third study group.[14] The activation protocols of the QH and Hyrax were similar among all studies. The QH appliance was activated 2 mm every 6 to 8 weeks until overcorrection was achieved. Activation was performed outside the mouth by using the helical loops of the QH appliance. The anterior arms on both sides were activated to provide expansion to the collapsed parts of the maxillary arch. The Hyrax appliance was activated two times a day, achieving 0.5-0.8 mm of expansion per day. When overcorrection was achieved, the retention phase was started. The only exception was the study by Abu Rub et al., in which the QH appliance was only activated at the time of its placement without any further reactivations.[17]

Measurements were made on physical or digital dental casts. All studies took an impression or scan before placement of the appliance. After expansion,

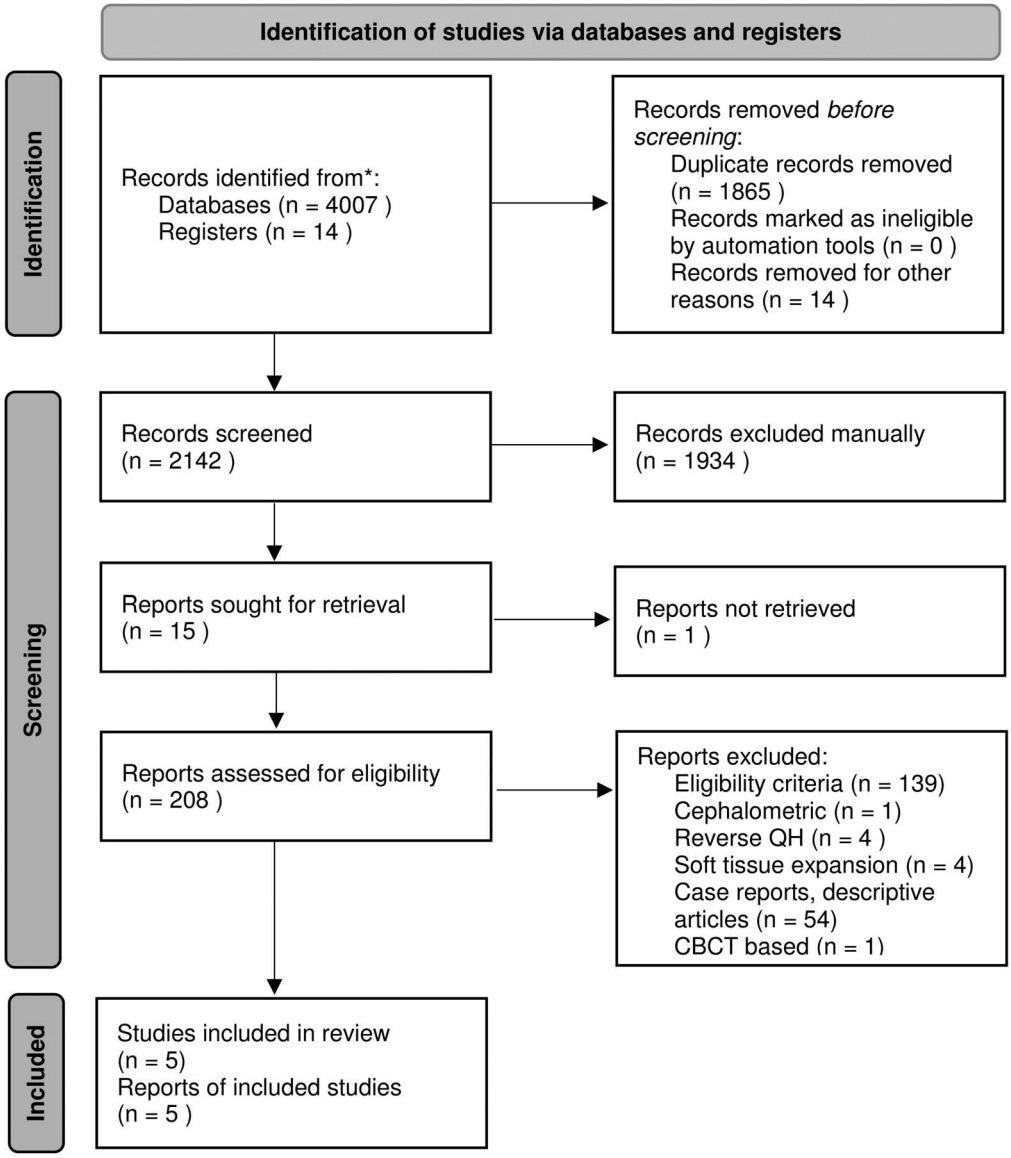

Figure 1. PRISMA flow diagram.

most studies stabilized the arch during a retention period varying from 3 months,[17] 6 months,[13,14] and up to 1 year.[15] Only the study by Vasant et al. made the impressions directly after the active expansion phase.[16] A detailed overview of the activation protocol, appliance design, and data collection of the included studies is presented in Table 3.

Results of SME and RME

Transverse Changes. Arch width and perimeter increased significantly with both SME and RME treatments.[13,17] Palatal depth did not increase with SME treatment but was significantly increased in patients treated with the Hyrax appliance.[13] Abu Rub et al. found no significant increase in palatal depth for SME or RME, measured as 0.50 mm and 0.46 mm, respectively.[17]

The QH appliance produced differential expansion with a statistically significantly greater increase in ICW compared with IMW.[13] In BCLP patients, no significant differences were found in differential openings of SME or RME.[13,15]

The molar width increase was not found to be different between SME and RME.[13,16] Patients treated with the RME appliance continued to have a slight transverse deficiency anteriorly and posteriorly according to Dalessandri et al.[15]

Pugliese et al. did not use a linear approach to make comparisons.[14] A total of 12 landmarks were identified and compared between the pre- and postexpansion digital models using generalized Procrustes imposition.

Table 2. Overview of the Included Studies and Their Characteristics[a]

Study	Study Design	Study Setting	Sample Size, n; Male/Female Ratio	Cleft Type, n	Age, Per Group	Intervention, n	Appliance	Outcomes	Results
Abu Rub et al. 2008[17]	Prospective cohort	Private hospital	n = 27; male/female: 12/15	UCLP: 12 BCLP: 15	10.8 y SME: 10 y RME: 11.5 y	SME: 13 RME: 14	QH RME	Changes in ICW, IMW, and palatal depth	QH group: **ICW,*** **IMW,*** palatal depth: NS RME group: **ICW,*** **IMW,*** palatal depth: NS
Vasant et al. 2009[16]	Prospective cohort	Military hospital	n = 20; male/female: 12/8	UCLP: 11 BCLP: 9	Mixed dentition before bone grafting	SME: 10 RME: 10	QH Hyrax	ICW change, IMW change, molar rotation, and molar tipping	IMW: NS ICW: NS **Molar rotation*** Molar tipping: NS
Alves et al. 2016[13]	Randomized clinical trial	University hospital	n = 50; male/female: 37/13	BCLP: 50	8.90 SME: 8.85 ± 0.99 RME: 8.95 ± 1.35	SME: 25 RME: 25	QH Hyrax	Changes in MDAW, MDAP, MDAL, palatal depth, and buccolingual inclination of 13, 15, and 16	MDAW (3-3, 4-4, 5-5, 6-6): NS MDAP: NS MDAL: NS Palatal depth: NS Buccolingual inclination: NS
Dalessandri et al. 2016[15]	Retrospective clinical trial	University hospital	n = 28; male/female: 20/8	UC: 7 BCLP: 4 CL: 7 STC: 10	6 y 3 mo–12 y 8 mo	SME: 17 RMA: 11	QH Hyrax	Comparison of maxillary ICW and IMW between healthy children and CLP patients	IMW: hyrax vs QH: NS **ICW: hyrax vs QH***
Pugliese et al. 2020[14]	Retrospective cohort	University hospital	n = 43; male/female: 26/17	BCLP: 43	7 y–10 y	SME: 15 Hyrax: 13 EDO: 15	QH Hyrax EDO	Intergroup comparison for maxillary dental arch shape and size at T1 and T2	Intergroup comparison for maxillary dental arch shape: Hyrax vs QH: NS **Hyrax vs EDO*** **QH vs EDO**** Intergroup comparison for maxillary dental arch size: NS

[a] BCLP indicates bilateral cleft lip and palate; CL, cleft lip; EDO, expander with differential opening; ICW, intercanine width; IMW, intermolar width; MDAL, maxillary dental arch length; MDAP, maxillary dental arch perimeter; MDAW, maxillary dental arch width; NS, not statistically significant; PCW, palatal cleft width; STC, soft tissue cleft; and UC, unilateral cleft; T1, before expansion; T2, after retention. Significant results in bold.
* $P < .05$; ** $P < .001$.

This method removes nonshape variation from the raw data, aiding in expressing pure shape differences between both groups. After expansion, a significantly different arch shape was found for both the QH and the differential expander when compared with the pretreatment measurements. Arch shape changed from an anteriorly narrow V-shape toward a U-shaped arch. No difference in arch shape was found for patients treated with the Hyrax appliance after expansion.[14]

Dental Tipping. Alves et al. found significant tipping only of the deciduous maxillary canines in both the SME and RME groups.[13] Buccal molar tipping was found to be significant for both expansion methods by Vasant et al., adding the ability of the QH appliance to rotate molars an average of 26.60°.[16]

Meta-Analysis. A meta-analysis was performed comparing the ratio of the anterior to posterior expansion in the SME and RME appliances. The measure of effect was defined as the mean difference between the SME and RME ratios. When including all studies reporting anterior and posterior dimensional changes, a trend toward a greater anterior-to-posterior ratio was noted for the SME group (Figure 2). When including only the studies reporting the same outcomes and also using the same activation protocol for the SME and RME appliances, a clear advantage toward SME for anterior expansion was found (Figure 3). Both meta-analyses presented signs of heterogeneity due to differences among the included studies, but the statistical significance held even after the Bonferroni correction was applied.

Risk of Bias and Quality of Evidence

The study by Alves et al. was an example of an RCT executed following the highest standards. It obtained excellent results in all categories of the RoB 2.0 tool, resulting in an overall low risk of bias.[13] Considering the cohort studies, some confounding and bias was detected, although not deemed serious. The cohort studies obtained a moderate score in the ROBINS I tool (Figures 4 and 5).

According to the GRADE assessment, the level of evidence for the result of the RCT was high and, for the cohort studies, moderate, indicating a mean difference

Table 3. Overview of the Activation Protocol and Data Collection of the Included Studies

Study	Moments of Data Collection	Data Collection at T1 and T2	Appliance Design	Treatment Time	Treatment Protocol
Abu Rub et al. 2008[17]	T1 = before expansion T2 = after retention	Plaster casts	Hyrax: banded first molars and first premolars[a] QH: banded first molars, extension up to canine	Active: Hyrax: 120 d QH: 160 d Retention: 3 mo	QH: preactivation without need for reactivation. Monthly check-up for 4 mo. Hyrax: 2 turns/d until the maxillary permanent first molar or the primary second molar palatal cusps were in contact with the mandibular buccal cusps or judged satisfactory by the clinician
Vasant et al. 2009[16]	T1 = before expansion T2 = directly after expansion	Plaster casts	Hyrax: banded first molars and first premolars[a] QH: banded first molars, extension up to canine	–	QH: activation every 6 wk (6 mm per activation) Hyrax: 2 quarter turns per d In both groups, the active phase was ended if the occlusal aspect of the maxillary lingual cusp of the permanent first molar or primary second molar contacts the occlusal aspect of the mandibular buccal cusp of the permanent first molar or primary second molar.
Alves et al. 2016[13]	T1 = before expansion T2 = after retention	Digital models of plaster casts	Hyrax: banded first molars and primary canines QH: banded first molars, extension up to canine	QH: 4 mo–21 mo Hyrax: 7 to 14 d Retention period: 6 mo	QH: initial activation and subsequent reactivations every 2 mo (6 mm/activation) Hyrax: 2 quarter turns twice per d
Dalessandri et al. 2016[15]	T1 = before expansion T2 = after retention	Three-dimensional scans of plaster casts	Hyrax: banded first molars and first premolars[a] QH: banded first molars, extension up to canine	Active: maximum 7 mo Retention: 5 mo–12 mo	Standardized activation protocol for RME and QH appliances
Pugliese et al. 2020[14]	T1 = before expansion T2 = after retention	Digital models of plaster casts	Hyrax: banded first molars and primary canines QH: banded first molars, extension up to canine	Retention: 6 mo	QH: activation every 2 mo (6 mm per activation) Hyrax: 2 quarter turns twice per d EDO: 2 quarter turns twice per d for both anterior and posterior screws In both the QH and EDO groups, the active phase was ended if the posterior maxillary teeth palatal cusps were aligned with the mandibular posterior teeth buccal cusps. If this situation was reached in the EDO group, activation of only the anterior expander screw was continued until an approximately 2-mm overcorrection was achieved in the canine region.

[a] When a mixed dentition was present, a deciduous molar was used instead of the first permanent premolar.

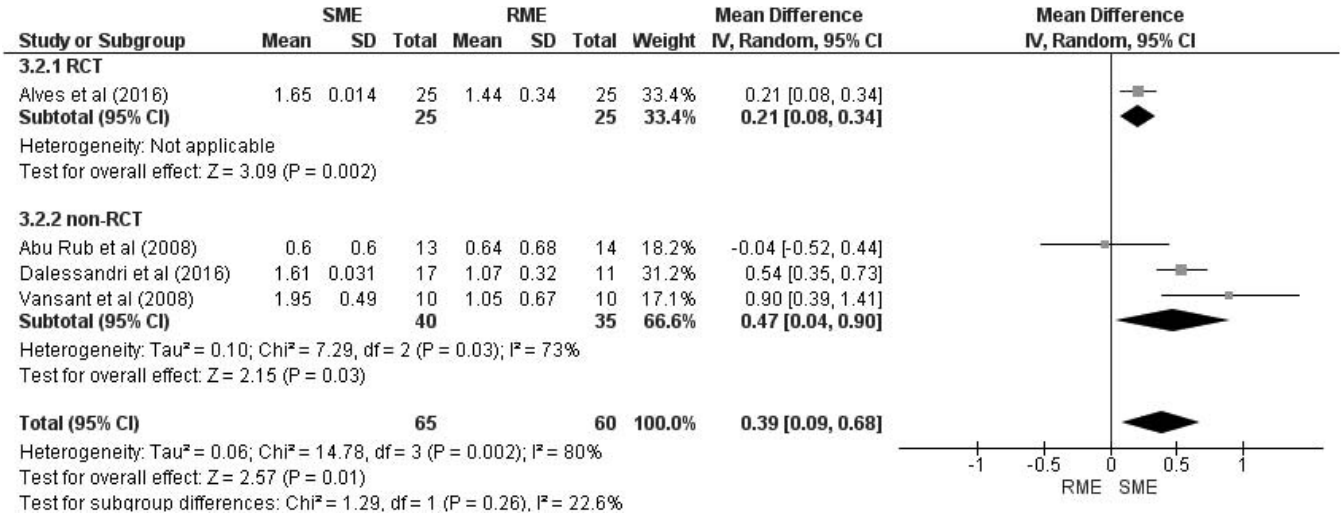

Figure 2. Forest plot comparing the ratio of anterior to posterior expansion in SME and RME.

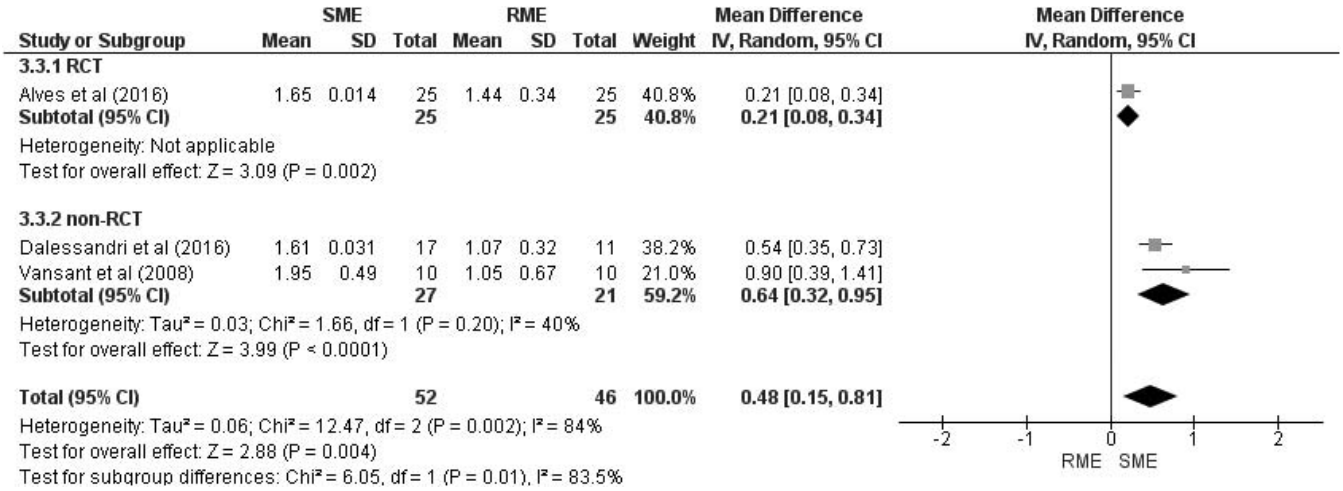

Figure 3. Forest plot comparing the ratio of anterior to posterior expansion in SME and RME for the studies with the same activation protocol.

in the anterior-to-posterior expansion ratio of 0.21 to 0.47 (Supplemental Table 2).

DISCUSSION

Summary of the Evidence

Transverse maxillary deficiency is a common problem in cleft patients before SABG. Correction of this transverse discrepancy is a key factor in the success and treatment outcome of SABG.[18] The results of this review and meta-analysis suggested that the SME performed with the QH appliance boasted the benefit of being able to provide more controlled anterior expansion. This is an advantage because the collapse of the arch in patients with CL/P is predominantly in the anterior region of the dental arch.[19]

The meta-analysis showed that the amount of expansion in the anterior region, in proportion to the amount in the posterior region, was larger with the QH appliance when compared with the Hyrax appliance. The heterogeneity of the cohort studies in the meta-analysis was significantly reduced by removing the study by Abu Rub et al.[17] That study was the only study in which the QH appliance was activated upon placement without any further reactivations, whereas in all other studies,[13–16] the QH appliance was activated every 6 to 8 weeks. The different outcome of that study might be explained by this difference in protocol because the differential activation possibility of the QH appliance was not used to the fullest.

Less differential opening with the Hyrax appliance may be attributed to the rigid design of the appliance. However, considering the evidence in noncleft patients in which the Hyrax promoted more anterior than posterior expansion because of the resistance of the circummaxillary sutures, it could be a competitor to the QH appliance in patients with CLP.[20,21] This is especially true for patients with BCLP, where symmet-

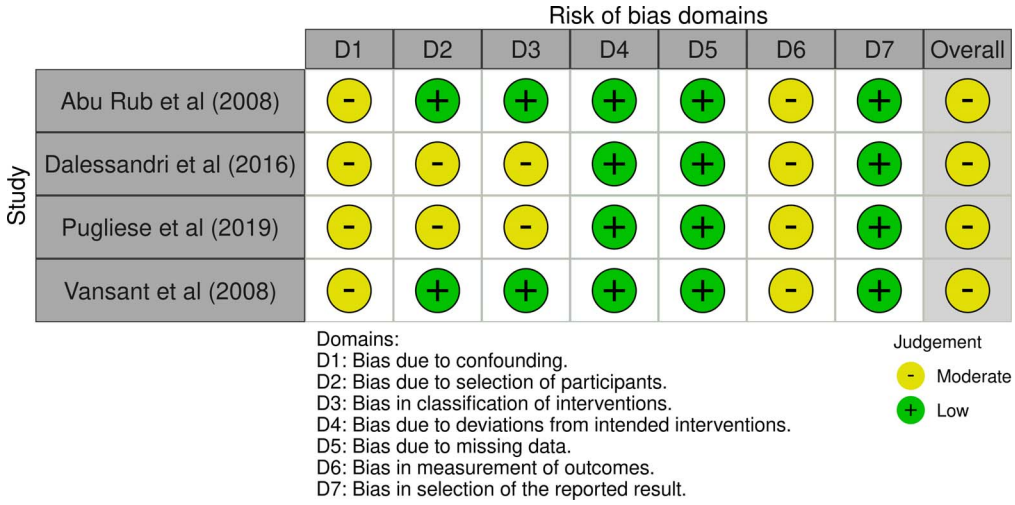

Figure 4. Traffic light plot of risk-of-bias assessments for nonrandomized studies.

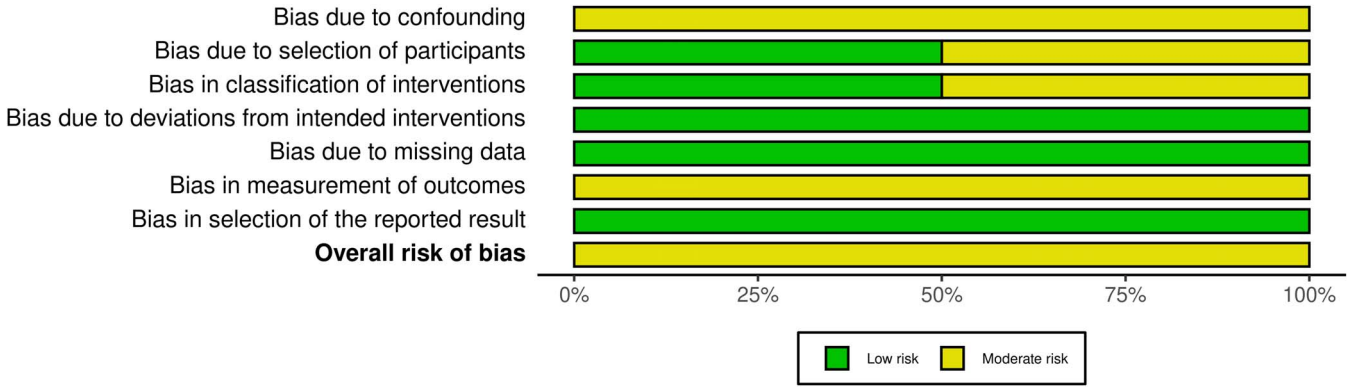

Figure 5. Weighted bar plot of risk-of-bias assessments for nonrandomized studies.

ric expansion is needed. This was in contrast with the results of this meta-analysis, suggesting that more anterior expansion was observed when using an SME strategy in patients with BCLP.[13,14] The dental arch form seems to be positively corrected with the use of differential expanders such as the QH appliance when compared with the Hyrax expander.[14]

This review showed that both SME and RME resulted in comparable posterior expansion. This was different from RME and SME comparisons in noncleft patients in which RME seemed to promote more posterior expansion.[10] No clear evidence exists about the influence of the palatal depth because the included studies reported conflicting results. Concerning the effect on the supporting teeth, no consensus was obtained. The RCT executed by Alves et al. found no difference in tipping of the molars; only the deciduous canines were affected[13] with no difference between the SME or RME groups. Vasant et al. found significant tipping of definitive molars in both groups.[16] A recent review of Rutili et al. found more molar tipping in the RME group in noncleft patients when compared with SME.[22] Probably less tipping was observed by Alves et al. because the resistance to expansion is lower in patients with CLP because of the absence of a complete midpalatal suture.

The Hyrax appliance is a rigid appliance. Molar bands are connected by rigid metal structures to the anterior teeth and to the contralateral teeth, achieving parallel expansion through activation of the jackscrew. The final goal is to transfer high forces through the teeth to the intermaxillary sutures to produce skeletal enlargement of the maxilla. In patients with CLP, the intermaxillary suture is nonexistent or at least partially weakened. Therefore, the resistance to expansion is minimal, and the rigid design allows only minimal deviation from the parallel expansion provided by the jackscrew. On the other hand, SME performed by the QH appliance allows for more regional control of expansion through its flexible and adaptable design. The loops and the connecting arms can be manipulated to adapt perfectly to the patient's need. Therefore, the Hyrax appliance may be preferred for use in BCL/P cases because both anterior segments are collapsed, and parallel expansion and more stabilization of both segments is necessary. When only a unilateral transverse discrepancy is present, such as in patients with UCL/P, the QH appliance is recommended.

Limitations

The current literature on comparisons of SME and RME in cleft patients is scarce. Because of the focus on presurgical expansion and the heterogeneity in follow-up time, it is difficult to draw conclusions concerning long-term stability. The comparison between SME and RME was eventually limited to a comparison between the Hyrax and QH appliances because of the lack of data for other appliances. Individual variation between patients, even those with the same cleft types, exists and may influence the results. The strongest limitation of the current review is the impossibility to create subgroups (BCL/P and UCL/P) because of the small sample sizes and sometimes unclear reporting of the included studies. Overall, sound methodology was used in the included studies, but the interstudy differences made it difficult to compare the results. Therefore, there is a need for well-designed randomized trials but especially the need for clear reporting and consent on what to measure and report. A Core Outcome Set should be developed for all cleft research, creating possibilities to pool data on a larger scale.

CONCLUSIONS

- SME and RME promote equal posterior expansion in cleft patients.
- Anterior differential expansion is greater with SME (QH appliance).

- No clear evidence exists concerning the amount of dental adverse effects of SME and RME in cleft patients.
- Further research should not only focus on methodology and inclusion criteria but also on establishing a Core Outcome Set.

SUPPLEMENTAL DATA

The Appendix with supplemental data is available online.

Disclosure

All authors declare no conflicts of interests. No funding was received for this research project.

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