Systematic Review Article

Can rapid maxillary expansion cause auditory improvement in children and adolescents with hearing loss? *A systematic review*

Nathalia Carolina Fernandes Fagundes[a]; Nicole Melres Rabello[a]; Lucianne Cople Maia[b]; David Normando[c]; Karina Corrêa Flexa Ribeiro Mello[d]

ABSTRACT

Objective: To evaluate whether the use of palatal expansion techniques can influence hearing loss in children and adolescents with previous hearing impairment.

Materials and Methods: Electronic searches in PubMed, Scopus, Web of Science, The Cochrane Library, Lilacs, OpenGrey, and Google Scholar were performed with a controlled vocabulary and free-text terms relating to palatal expansion and hearing loss. No language or time restrictions were imposed. Clinical trials that focused on human patients treated with rapid or semirapid maxillary expansion in children and teenagers with hearing loss were included. Data extraction was undertaken by two authors, with conflict resolution by a third author. Risk of bias assessment and data extraction were performed on the selected studies.

Results: Seventy-four citations were retrieved by the search. Initially, 12 studies were selected according to the eligibility criteria, but three studies were excluded because of the presence of adults, absence of hearing level evaluation, and oversampling, resulting in nine studies. The mean improvement in hearing levels varied from 2 to 19 dB among the studies. The risk of bias varied from low to moderate risk.

Conclusions: The evidence indicated that there was a hearing improvement after maxillary expansion in patients with hearing loss in the evaluated studies, although more controlled and randomized studies are necessary to investigate this issue further. (*Angle Orthod.* 2017;87:886–896.)

KEY WORDS: Maxillary expansion; Hearing loss

INTRODUCTION

The palatal expansion technique is a therapeutic approach that has as its main objective the correction of a transverse discrepancy in the upper arch, through the expansion of the sutures.[1,2] Clinically, the indications for this procedure are associated with maxillary atresia, posterior crossbite, dental crowding, or nasal stenosis.[1,3]

Although its main purpose is to correct a narrow upper arch, adjacent areas such as the mandible, nasal cavity, pharyngeal structure, temporomandibular joint, middle ear, and pterygoid process of the sphenoid bone[3,4] change after this procedure. Rapid maxillary expansion (RME) and semirapid maxillary expansion (SRME) have also been linked to improvements for patients with impaired breathing, enuresis, and hearing loss, especially in growing children who have maxillary constriction.[5–7]

[a] Student, Department of Orthodontics, Brazilian Association of Dentistry, Belém, Pará, Brazil

[b] Professor, Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Rio de Janeiro, Brazil

[c] Professor, Department of Orthodontics, School of Dentistry, Universidade Federal do Pará (UFPA), Belém, Pará, Brazil

[d] Professor, Department of Orthodontics, Brazilian Association of Dentistry, Belém, Pará, Brazil

Corresponding author: Dr Nathalia Carolina Fernandes Fagundes, Department of Orthodontics, Brazilian Association of Dentistry, Trav. Marques de Herval, 2298, Belém-Pará 66.087-320, Brazil
(e-mail: nathaliafag@hotmail.com)

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The first reports describing an association between improvements for patients with hearing loss and RME are from the 1960s[8] and early 1980s.[6] The investigation of hearing improvements after palatal expansion, as well as the magnitude and stability of this process, shows an important aspect of its direct impact on the quality of life of the juvenile patient. Improvements in hearing can occur after RME, especially in cases of conductive hearing loss derived from changes in the middle ear and Eustachian tube. Moreover, resolution may improve school performance and quality of life,[9] an important additional beneficial effect in pediatric patients with maxillary constriction who have such injury.

Maxillary expansion is an effective technique in the treatment of transverse problems.[1,2] However, doubts remain about its additional effects and usage as adjuvant therapy in patients with hearing loss who request maxillary expansion.

This systematic review aimed to evaluate whether the palatal expansion technique can improve hearing loss in children and adolescents with preexisting hypoacusis. The type of rapid expansion (rapid or semirapid), stability, and magnitude of changes reported were also evaluated.

MATERIALS AND METHODS

This systematic review was registered at PROSPERO database (http://www.crd.york.ac.uk/PROSPERO) under registration code CRD42015030188 and performed according to Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.[10]

Eligibility Criteria

The PICO strategy was followed in this systematic review. Prospective and retrospective studies in hearing impaired children and adolescents (P) treated (I) and untreated/before treatment (C) with some palatal expansion approach, in which the main outcome was the influence of expansion on hearing loss (O), were included. Opinion articles, technical articles, guides, and animal studies were excluded.

Search Strategy and Study Selection

Searches were conducted in the following electronic databases, without language restriction, until May 2017: PubMed, Scopus, Web of Science, The Cochrane Library, LILACS, OpenGrey, and Google Scholar. All publications presented in the databases contained a combination of controlled predefined MeSH and free terms related to hearing loss and RME/SRME used with Boolean operators (or, and) to combine searches. The previously defined terms were adapted to the rules of syntax of each bibliographic database.

After consultation of the databases, duplicated results were removed from the combination of the results obtained from all surveyed sources. Additional citations were sought from the analysis of the reference list of all previously selected articles. The searches were conducted by two examiners (Dr Fagundes and Dr Rabello) and checked by a third examiner (Dr Mello) in cases of disagreement.

After the removal of duplicates, the titles and abstracts that did not fit the established eligibility criteria were excluded. The resulting articles were evaluated and judged by their full texts. The process of the search strategy is shown in Figure 1.

Data Extraction and Risk of Bias

All relevant citations were saved in a bibliographic reference manager (EndNote, x7 version, Thomson Reuters) and, at first, titles and abstracts were analyzed according to the inclusion and exclusion criteria. The selected studies were evaluated by full text, and a final selection was performed.

The quality assessment and risk of bias (RoB) of the included studies were performed following the ROBINS-I tool (Risk of Bias in Non-randomized Studies-of Interventions).[11] This checklist included three main domains of bias: preintervention, at intervention, and postintervention. The RoB was judged for each domain and to overall evaluation as low, moderate, serious, critical, or no information for all included studies (Table 1).

The results extracted from the selected articles were qualitatively evaluated. A quantitative evaluation of the studies seemed inappropriate given the methodological heterogeneity of the selected articles.

RESULTS

Study Selection and Characteristics

A total of 74 studies were identified from the searches, with exclusion of 34 duplicated results. The remaining 40 titles and abstracts were analyzed according to the inclusion and exclusion criteria, with the exclusion of 28 studies. The remaining studies ($n = 12$) were evaluated by full text, and three were excluded. Two of these were excluded because of a conflict with the PICO strategy: one study included adult patients in the sample,[12] and the other did not evaluate hearing levels.[13] The third study was excluded because of overlapping samples of two articles,[14,15] and only the study by De Stefano et al.[14] was selected. As a result, nine studies[7,14,16–22] were included in this review (Figure 1).

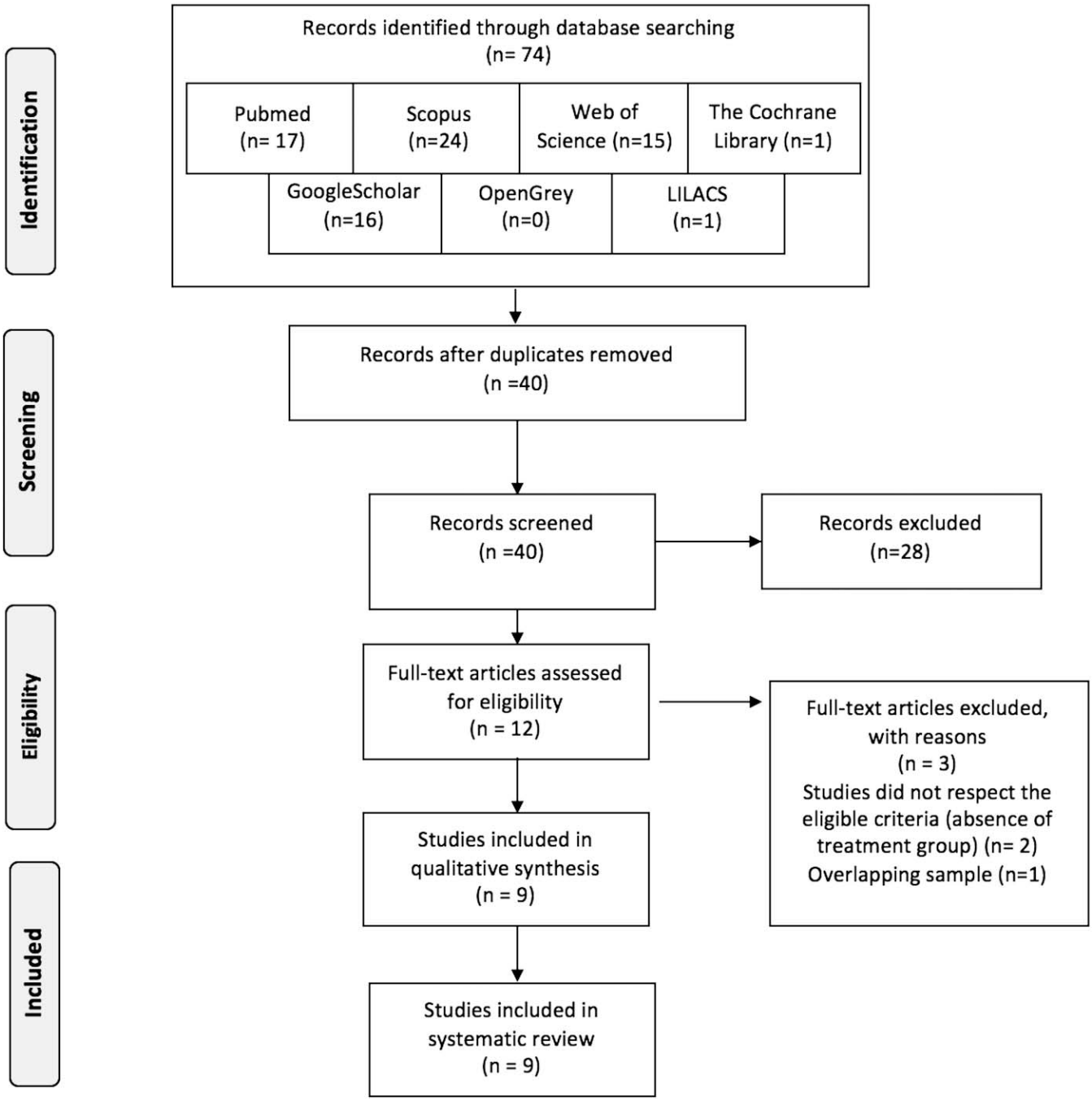

Figure 1. Flow chart with number of records identified and removed at each stage of the review according to PRISMA statement.

After the RoB evaluation, two studies[20,21] were ranked as low risk and seven[7,14,16–19,22] as moderate risk. At the domains "Bias due to Confounding," "Bias in Selecting Participants for the Study," "Bias due to Deviations From Intended Intervention," "Bias due to Missing Data," and "Bias in Selecting Reported Result," a low RoB was reported for all studies. A moderate RoB was observed in most of the studies to the domain "Bias in Measuring Outcome," except to Micheletti et al.[21] and Kiliç et al.,[20] which presented low RoB. The domain "Bias in Classifying Interventions" also reported moderate RoB to some studies. No article presented serious RoB in any domains of this tool (Table 2).

The characteristics of the selected studies regarding the qualitative analysis are shown in Table 3. Among the nine[7,14,16–22] articles included, all studies were prospective nonrandomized clinical trials.

Table 1. BIAS and Domains Considered in Risk of Bias (RoB) Evaluation According to the ROBINS-I Tool[11]

Domains of Bias	Description
Preintervention	
Bias due to confounding	Baseline confounding: presence of unmatched numbers of participants by age and hearing problems at study start Time-varying confounding: a period smaller than 4 mo for retention; appearance of infections or inflammatory processes that can alter the hearing condition; absence of the amount of expansion performed
Bias in selecting participants for study	Exclusion of some eligible participants or the initial follow-up time of some participants
At intervention	
Bias in classifying interventions	When intervention status (presence of hearing loss) was misclassified or in the absence of precise diagnosis of hearing loss; it was also considered as a possible bias in the case of use of different methods for maxillary expansion
Postintervention	
Bias due to deviating from intended intervention	When there are systematic differences between the intervention (RME group) and comparator groups in the care provided or when there was no information of the achievement of a succcessful RME, in case of absence of a control group
Bias due to missing data	In occurrence of loss to follow-up, incomplete data collection, and exclusion of participants from analysis
Bias in measuring outcomes	When outcomes (hearing levels) were misclassified or measured with error, when different methods are used to assess outcomes in different intervention groups
Bias in selecting reported result	Selective reporting of results, when the effect of all outcome measurements were not fully reported
Judgment for each domain	
Low RoB	Study is comparable to a well-performed, randomized trial with regard to this domain
Moderate RoB	Study is sound for a nonrandomized study with regard to this domain but cannot be considered comparable to a well-performed, randomized trial
Serious RoB	Study has some important problems in this domain
Critical RoB	Study is too problematic in this domain to provide any useful evidence on the effects of intervention
No information	No information on which to base a judgment about risk of bias for this domain
Overall judgment	
Low RoB	Study is judged to be at low risk of bias for all domains
Moderate RoB	Study is judged to be at low or moderate risk of bias for all domains
Serious RoB	Study is judged to be at serious risk of bias in at least one domain but not at critical risk of bias in any domain
Critical RoB	Study is judged to be at critical risk of bias in at least one domain
No information	No clear indication that the study is at serious or critical risk of bias, and there is a lack of information in one or more key domains of bias (a judgment is required for this)

Results of Individual Studies

Eight[7,14,16–20,22] of the nine studies reported an improvement in hearing levels, and the other study, which was by Micheletti et al.,[21] reported no differences after RME or between the treatment and control groups. Two studies included a control group: Micheletti et al.[21] had a control group with RME and without

Table 2. Risk of Bias (RoB) of the Included Studies, According to the ROBINS-I Tool[11]

	Domain							
	Preintervention		At Intervention	Postintervention				
Author	Bias due to Confounding	Bias in Selecting Participants for the Study	Bias in Classifying Interventions	Bias due to Deviations From Intended Intervention	Bias due to Missing Data	Bias in Measuring Outcomes	Bias in Selecting Reported Result	Overall Risk of Bias Judgment
Taspinar et al.[7]	Low	Low	Low	Low	Low	Moderate	Low	Moderate
De Stefano et al.[14]	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Ceylan et al.[16]	Low	Low	Moderate	Low	Low	Moderate	Low	Moderate
Cozza et al.[17]	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Kilic et al.[18]	Low	Low	Moderate	Low	Low	Moderate	Low	Moderate
Kilic et al.[19]	Low	Low	Moderate	Low	Low	Moderate	Low	Moderate
Kilic et al.[20]	Low	Low	Low	Low	Low	Low	Low	Low
Micheletti et al.[21]	Low	Low	Low	Low	Low	Low	Low	Low
Villano et al.[22]	Low	Low	Low	Low	Low	Moderate	Low	Moderate

Table 3. Summary of Characteristics and Results of the Included Studies[a]

Author/Country/ Year/ Study Design	Participants			Palatal Expansion Characteristics
	Source of Sample	n	Age, Mean (SD), y	
Taspinar et al.[7]/ Turkey/2003/ Prospective	Department of Orthodontics, School of Dentistry, Ataturk University	35	14.5	Hyrax appliance Observation period: before RME, after satisfactory expansion (18 d later) end of retention (about 6 mo), and at the end of fixed-appliance treatment (approximately 2 y) Protocol of activation: 3 times/d for 3 d; after midpalatal suture opening: 2 times/d until the complete elimination of the posterior crossbite
De Stefano et al.[14]/Italy/2009/ Prospective	—	27	7	Hyrax appliance Observation period: before RME; after RME removal (6 mo) and after 12 mo Activation protocol: one-quarter turn (0.25 mm) in the morning and another quarter turn in the evening every day until the upper molar palatal cusps were in contact with the lower molar buccal cusps
Ceylan et al.[16]/ Turkey/1996/ Prospective	Department Orthodontics, School of Dentistry, Ataturk University	14	12.9 (±1.75)	Hyrax appliance Observation period: before RME, after satisfactory widening at the midpalatal suture, after retention period (approximately 4.5 mo) Activation protocol: two turns of 0.2 mm per day until the posterior crossbite was eliminated
Cozza et al.[17]/ Italy/2007/ Prospective	Department of Orthodontics, School of Dentistry, University of Rome Tor Vergata	24	7	Butterfly expander Observation period: before RME, after retention period (after 6 mo) Activation protocol: one-quarter turn three times a day until overcorrection of molar transverse relationship by 2–3 mm for each side
Kilic et al.[18]/ Turkey/2008/ Prospective	Department of Orthodontics, Faculty of Dentistry, Ataturk University	15	13.43 (±0.8)	Rigid bonded acrylic appliance Observation period: before RME, end of expansion, end of retention period, and after fixed appliance treatment (approximately 2 y) Activation protocol: twice a day, until adequate expansion was achieved
Kilic et al.[19]/ Turkey/2008/ Prospective	Department of Orthodontics, Faculty of Dentistry, Atatürk University	19	13.4 (±1)	Rigid bonded acrylic appliance Observation period: before RME, end of expansion (3.4 mo), end of retention period (6 mo), end of fixed appliance treatment (approximately 2 y) Activation protocol: one turn (0.2 mm) twice a day during the first 5–7 days; after suture opening, two turns a day, three times a week, until result in 2 mm of overexpansion, clinically determined
Kilic et al.[20]/ Turkey/2016/ Prospective	Department of Orthodontics, Faculty of Dentistry, Atatürk University	26 RME group: n = 15 Control: n = 11	RME group: 10.07 ± 2.72 Control: 8.34 ± 2.46	Rigid bonded acrylic appliance or Hyrax appliance Observation period: before RME, after RME, and after an observation period of 10 mo Activation protocol: Two times a day: one-quarter turn in the morning (0.2 mm) and one in the evening (0.2 mm) until the crossbites were eliminated and 2–3 mm overexpansion was achieved
Micheletti et al.[21]/ Brazil/2012/ Prospective	—	18 RME group with hearing loss = 9 RME without hearing loss) = 9	8.1 (±3.7)	Haas expander Observation period: before RME, after RME, 3 mo after RME, 1 y after RME Activation protocol: Two turns every day (0.5 mm/d), during 15–20 d
Villano et al.[22]/ Italy/2006/ Prospective	—	25	7.24 (±0.58)	A fixed appliance with two or four bands Observation period: before RME, after expansion (7–14 d), and after retention period (8 mo) Activation protocol: three times a day for 7 to 14 days until the need of each individual

[a] The results were presented as mean ± standard deviation or mean in decibels (dB). ANOVA indicates analysis of variance; LSD, Least Square Difference; NA, Not Applicable; RME, rapid maxillary expansion; SRME, semi-rapid maxillary expansion.
[b] Difference between hearing levels after pure-tone audiograms in decibels.

Table 3. Extended

Audiological Evaluation (Unit of Measurement)	Results	Statistical Analysis	Mean Improvement[b]	
			After Expansion	After Retention/ Follow-up
Pure-tone audiograms (dB)	The improvements between the first (before RME: 24.45 ± 7.4 dB) and all other recordings (after RME: 20.63 ± 7.08 dB; end of retention: 20.95 ± 7.13 dB, after 2 y: 20.75 ± 7.32) were statistically significant ($P < .001$). The changes between the second and third recordings, the second and fourth recordings, and the third and fourth recordings were not statistically significant.	ANOVA and LSD	3.83	3.7
Pure-tone audiograms (dB) and tympanometry (dB)	An improvement in mean values of air-bone gaps was recorded before (32.03 dB) and after removal of RME appliance (12.91 dB), which was stable after 12 mo (12.91 dB).	Descriptive analysis only	19.12	19.12
Pure-tone audiograms (dB).	Hearing levels were improved between first (before RME 20.39 ± 11.78 dB) and second audiogram (after RME 17.54 ± 12.59 dB, $P = .043$). No difference was observed between third audiogram (after retention period 18.18 ± 6.83 dB) and the other groups.	ANOVA and LSD	2.85	2.21
Pure-tone audiograms (degree of conductive hearing loss) and impedenzometry (score: endotympanic compliance)	Improvement in conductive hearing loss and hearing levels after retention period	Descriptive statistics only	NA	NA
Pure-tone audiograms (dB) and tympanometry (dB)	Hearing levels were improved at statistically significant levels during the active widening period (before RME: 19.42 ± 7.87 dB and after RME: 16.33 ± 7.25 dB; $P < .05$) and after fixed appliance treatment periods (after RME: 16.33 ± 7.25 dB and end of treatment: 13.83 ± 6.68 dB: $P < .001$).	ANOVA and LSD	4.97	4.14
Pure-tone audiograms (dB) and tympanometry (dB)	Hearing levels were improved during the active widening period (before SRME: 20.66 ± 8.85 dB and after SRME: 15.69 ± 6.25 dB; $P < .001$), and the results remained stable during the retention and fixed appliance treatment periods (end of retention: 16.32 ± 6.67 dB and after treatment: 16.52 ± 6.68).	ANOVA and LSD	3.09	5.59
Pure-tone audiograms (dB)	In the control group, hearing threshold decreased significantly (approximately 3 dB: at beginning: 12.55 ± 2.15 dB and end: 9.30 ± 2.58 dB; $P < .01$) during the observation periods. In the RME group, hearing threshold decreased approximately 15 dB after maxillary expansion (before RME: 30.42 ± 11.20 dB and after RME: 16.48 ± 6.73 dB; $P < .001$) and remained relatively stable during the observation period (after 10 mo: 15.68 ± 8.52 dB).	ANOVA and Bonferroni correction	13.94	14.74
Pure-tone audiograms (dB) and tympanometry (pressure and compliance of tympanic membrane)	There were no significant variations on the hearing levels in periods studied ($P > .05$). RME can improve middle ear function in children with posterior crossbite after 1 y. RME has no deleterious effect on hearing quality.	ANOVA and Mann-Whitney test	NA	NA
Pure-tone audiograms (dB), tympanometry (dB), and video-otoscopy (descriptive evaluation)	An improvement in hearing levels was observed after RME at 1000–2000 Hz (before RME: 31.6 ± 5.76 dB and after RME: 26.9 ± 4.33 dB; $P < .001$) and 2000–4000 Hz (before RME: 29 ± 3.65 dB and after RME: 21.4 ± 3.52 dB; $P < .0001$) but not at 250–1000 Hz. The hearing levels also showed improvement after the retention period at all frequencies compared (before RME 32.89 ± 5.01 dB and after retention: 17.36 ± 2.11 dB; $P < .0001$), as well as after RME and the retention period (after RME: 28.58 ± 4.41 dB and after retention: 17.36 ± 2.11 dB; $P < .0001$).	ANOVA	4.31	15.53

hearing problems; Kiliç et al.[20] used a control group without RME intervention or hearing problems. The follow-up of treated patients ranged from the total period of expansion appliance retention[16,17,22] to 10 months,[2] 1 year,[14,21] or 2 years.[7,18,19] The sample size ranged from 14 patients[16] to 35 patients,[7] with an age range of 7 years[14,17] to 14.5 years,[7] including both sexes. In all studies, the expansion method involved the use of cemented and fixed appliances activated two to three times a day, ranging from 3 to 20 days. The methods used for the audiological analysis included audiograms,[9,14–17] tympanograms,[9,16–18] video-otoscopy,[16] and impedance tests.[9,15–18]

Among the nine studies, only two articles[17,21] did not report the hearing improvements in numerical form. The mean hearing improvements reported by the articles ranged from 2.85 dB[16] to 19.12 dB[14] after maxillary expansion and from 2.21 dB[16] to 19.12 dB[14] after the retention period or follow-up period among the evaluated studies (Table 3).

DISCUSSION

An improvement in hearing levels was found in most studies after maxillary expansion and at the end of the retention or follow-up period, with improvements in hearing levels varying from approximately 2 to 19 dB. The evaluated studies were all nonrandomized and presented considerable variation in sample characteristics, treatment features, methods of hearing level evaluation, and follow-up period, presenting a risk of bias varying from low to moderate among the selected studies.

The main results analyzed were the hearing levels after maxillary expansion in children and adolescents with previous hearing loss. Seven[7,14,17–20,22] studies described an improvement in hearing levels after maxillary expansion that lasted until the end of the appliance retention period or longer. This result could represent an additional positive effect of maxillary constriction treatment.

A relationship between maxillary constriction and hearing was previously proposed to be related to the Eustachian tubes, the middle ear, and mouth breathing.[8] A correlation was shown between conductive hearing loss and this maxillary condition[23] in subjects between 7 to 40 years with a posterior crossbite and a high palatal vault. The mechanism linking maxillary expansion and hearing improvement may be related to soft tissue changes. The correction of the palatal anatomy can influence muscular function, with the stretching of the elevator and tensor veli palatine muscles, thus allowing for correct function of the tympanic membrane and the auditory system.[24,25] Moreover, there may be a possible association between maxillary expansion and the attenuation of infectious processes.[26]

Controversially, Ceylan et al.[16] was the only study included that described a complete reversion of hearing improvement after the retention period. In that study, the sample consisted of 11 female and 3 male participants, from 10.3 to 16.8 years of age, and clear information about the hearing problems of patients at the beginning was not presented. The authors associated this reversion with possible relapse in the RME procedure.

Evaluation of the stability of hearing improvement for a longer period was described by three of the studies, with follow-up periods of 10 months,[20] 1 year,[14,21] or 2 years.[7,18,19] In all of those studies, improvement in hearing levels was observed at the end of the retention period and became stable after a longer follow-up. In the studies with a 2-year follow-up, a transpalatal arch was used[7,18,19,27] for retention after removal of the maxillary expansion appliance.

Two different types of maxillary expansion were described in the articles: RME[7,14,16–18,20–22] and SRME.[19] Despite the different protocol of activation in SRME, all included studies reported the use of orthopedic appliances to achieve palatal suture opening, with consequent treatment of the posterior crossbite as a parameter of maxillary expansion success.

The instrument selected for RoB assessment showed a moderate RoB in eight studies evaluated and reported a low risk in two studies[20,21] on the question researched (Table 2). The problems regarding the domains “Bias in Measuring Outcomes” and “Bias in Classifying Interventions” were highlighted. The domain “Bias in Classifying Interventions” was marked as moderate for three articles because of the lack of data regarding hearing problems.[16,18,19] The domain “Bias in Measuring Outcomes” was considered moderate in seven studies because of the absence of a control group.[7,14,16–19,22]

Seven[7,14,16–19,22] of the evaluated studies did not include an untreated control group, and none of the studies were randomized. This fault was also cited in other systematic reviews that evaluated additional effects of RME,[23–25] especially regarding long-term evaluations.[25] In all of the studies, the steps of palatal expansion were compared: before expansion, after expansion, and/or after the retention period for each subject involved.

In addition, in the studies with a control group, the difference between hearing levels was compared between the RME and control groups. Characteristics of the control groups differed between those two studies. Micheletti et al.[21] described a control group with maxillary constriction and absence of hearing loss who underwent RME and were observed for the same period as the RME group with hearing loss, and Kiliç et

al.[20] reported a control group observed for the same period of the case group, without RME or hearing loss.

The isolation of the effects resulting from the expansion and hearing loss in patients with maxillary constriction and hearing loss from the comparison with an untreated group should be an ideal scenario for the accomplishment of this type of study.[28] Therefore, more robust studies are needed to clarify the anatomical changes resulting from the expansion of maxilla, which may guide the possible therapeutics of this procedure in other aspects, as for the case of hearing loss.

The similar designs among the studies selected for this systematic review might be related with their origin since five[7,16,18–20] of the nine studies included were from the same department of the same university. Even though an independent sample was described in each study, this kind of conformity can induce confounding effects and increase the RoB in sample selection.[29]

In addition, poor information was provided about the audiological condition of the subjects. Two studies reported otitis,[14,17,22] and other papers described conductive hearing loss/middle ear dysfunction.[7,16,18–21] In this context, four studies[7,16,18,19] classified the level of hearing impairment before RME intervention but showed no differences in the final hearing assessments. In addition, the type of ear dysfunction described among the studies showed no relationship with the changes in hearing observed. Moreover, most studies lacked a statement on the blinding assessment,[16,18,19,22] and this was probably related to the main topic of this study. Perhaps the blinding of examiners or patients was not feasible because of the uncontrolled nature of the studies and the use of maxillary expansion appliances.

Considering the methods of hearing evaluation, most of them were concentrated on audiometric examinations, with measurements of threshold hearing levels and the air-bone gap. The pure-tone audiogram is considered the gold standard for the assessment of hearing loss,[30,31] aside from measuring the level of recognition of pure-tone sounds at different frequencies.[28] The audiometric test was performed in all studies, along with other examinations such as tympanograms,[14,18,19,21,22] video-otoscopy,[22] and impedance testing[17] to evaluate the intrinsic factors associated with hearing loss. Tympanometry evaluates the transmission and pressure of the middle ear and helps to assess changes in the tympanic membrane.[32,33] All of the included studies conducted this evaluation, but statistical analysis was carried out in only two of them.[18,19] The results showed an increase in middle ear volume[14,18,19] and the stabilization of normal pressure levels[21,22] of the tympanic membrane after a qualitative analysis.

Finally, maxillary expansion is a safe treatment to correct maxillary constriction in growing children and adolescents.[3] The effects of this treatment in children and adolescents with conductive hearing impairments may contribute to an increase in quality of life.[16] However, there are few previous studies on this theme in the literature, mostly case reports and literature reviews. This systematic review showed that the existing prospective studies exhibited qualitative pitfalls, which suggests the need for further primary studies focused on the additional effects of palatal expansion.

CONCLUSIONS

- The evidence available indicated that there is an improvement in hearing loss after maxillary expansion in children and adolescents with hearing impairments.
- However, more well-conducted studies are necessary to ensure a more reliable conclusion.

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APPENDIX 1
Database and Search Strategy

Database	Search Strategy
PubMed	#1- ((((((((((Child[MeSH Terms]) OR Child[Title/Abstract]) OR Adolescent[MeSH Terms]) OR Adolescent[Title/Abstract]) OR Adolescents[Title/Abstract]) OR Adolescence[Title/Abstract]) OR Teen[Title/Abstract]) OR Teens[Title/Abstract]) OR Youth[Title/Abstract]) OR Youths[Title/Abstract]) OR Teenagers[Title/Abstract]) OR Teenager[Title/Abstract] #2- ((((((((((((Hearing loss[MeSH Terms]) OR Hearing loss[Title/Abstract]) OR Hypoacusis[Title/Abstract]) OR Hypoacuses[Title/Abstract]) OR Hearing Impairment[Title/Abstract]) OR Conductive hearing loss[Title/Abstract]) OR Hearing[Title/Abstract]) OR Hearing level[Title/Abstract]) OR Hearing disabilities[Title/Abstract]) OR Auditory apparatus[Title/Abstract]) OR Auditory meatus[Title/Abstract]) OR Auditory canal[Title/Abstract]) OR Ear hearing[Title/Abstract]) OR Ear canal[Title/Abstract] #3- (((((((((Palatal expansion technique[MeSH Terms]) OR Palatal expansion technique[Title/Abstract]) OR Palatal expansion techniques[Title/Abstract]) OR Maxillary expansion[Title/Abstract]) OR RME[Title/Abstract]) OR Rapid maxillary expansion[Title/Abstract]) OR Rapid palatal expansion[Title/Abstract]) OR Palatal disjunction[Title/Abstract]) OR Maxillary disjunction[Title/Abstract]) OR Maxillary constriction[Title/Abstract] Final search: #1 AND #2 AND #3
Scopus	((TITLE-ABS-KEY (“Palatal expansion technique”) OR TITLE-ABS-KEY (“Palatal expansion techniques”) OR TITLE-ABS-KEY (“Maxillary expansion”) OR TITLE-ABS-KEY (rme) OR TITLE-ABS-KEY (“Rapid maxillary expansion”) OR TITLE-ABS-KEY (“Rapid palatal expansion”) OR TITLE-ABS-KEY (“Palatal disjunction”) OR TITLE-ABS-KEY (“Maxillary disjunction”) OR TITLE-ABS-KEY (“Maxillary constriction”))) AND ((TITLE-ABS-KEY (“Hearing loss”) OR TITLE-ABS-KEY (hypoacuses) OR TITLE-ABS-KEY (“Hearing Impairment”) OR TITLE-ABS-KEY (“Conductive hearing loss”) OR TITLE-ABS-KEY (hearing) OR TITLE-ABS-KEY (“Hearing level”) OR TITLE-ABS-KEY (“Hearing disabilities”) OR TITLE-ABS-KEY (“Auditory apparatus”) OR TITLE-ABS-KEY (“Auditory meatus”) OR TITLE-ABS-KEY (“Auditory canal”) OR TITLE-ABS-KEY (“Ear hearing”) OR TITLE-ABS-KEY (“Ear canal”))) AND ((TITLE-ABS-KEY (child*) OR TITLE-ABS-KEY (adolescen*) OR TITLE-ABS-KEY (teen*) OR TITLE-ABS-KEY (youth*) OR TITLE-ABS-KEY (teenager*)))
Web of Science	#1- ((((((((((Tópico: (Child) OR Tópico: (Children)) OR Tópico: (Adolescent)) OR Tópico: (Adolescents)) OR Tópico: (Adolescence)) OR Tópico: (Teen)) OR Tópico: (Teens)) OR Tópico: (Youth)) OR Tópico: (Youths)) OR Tópico: (Teenagers)) OR Tópico: (teenagers)) #2- ((((((((((((Tópico: (“Hearing loss”) OR Tópico: (hyperacusis)) OR Tópico: (hypoacusis)) OR Tópico: (“Hearing Impairment”)) OR Tópico: (“Conductive hearing loss”)) OR Tópico: (Hearing)) OR Tópico: (“Hearing level”)) OR Tópico: (“Hearing disabilities”)) OR Tópico: (“Auditory apparatus”)) OR Tópico: (“Auditory meatus”)) OR Tópico: (“Auditory canal”)) OR Tópico: (“Ear hearing”)) OR Tópico: (“Ear canal”)) #3- Tópico: (“Palatal expansion technique”) OR Tópico: (“Palatal expansion techniques”) OR Tópico: (“Maxillary expansion”) OR Tópico: (RME) OR Tópico: (“Rapid maxillary expansion”) OR Tópico: (“Rapid palatal expansion”) OR Tópico: (“Palatal disjunction”) OR Tópico: (“Maxillary disjunction”) OR Tópico: (“Maxillary constriction”) Final search: #1 AND #2 AND #3
The Cochrane Library	Child OR Children OR Adolescent OR Adolescents OR Adolescence OR Teen OR Teens OR Youth OR Youths OR Teenagers OR Teenagers in Title, Abstract, Keywords and “Hearing loss” OR hyperacusis OR hypoacusis OR “Hearing Impairment” OR “Conductive hearing loss” OR Hearing OR “Hearing level” OR “Hearing disabilities” OR “Auditory apparatus” OR “Auditory meatus” OR “Auditory canal” OR “Ear hearing” OR “Ear canal” in Title, Abstract, Keywords and “Palatal expansion technique” OR “Palatal expansion techniques” OR “Maxillary expansion” OR RME OR “Rapid maxillary expansion” OR “Rapid palatal expansion” OR “Palatal disjunction” OR “Maxillary disjunction” OR “Maxillary constriction” in Title, Abstract, Keywords in Trials’
LILACS	(Child$ OR Adolescen$ OR Teen$ OR Youth$ OR Teenager$) AND ((Hearing loss) OR hyperacusis OR hypoacusis OR (Hearing Impairment) OR (Conductive hearing loss) OR Hearing OR (Hearing level) OR (Hearing disabilities) OR (Auditory apparatus) OR (Auditory meatus) OR (Auditory canal) OR (Ear hearing) OR (Ear canal)) AND ((Palatal expansion technique) OR (Palatal expansion techniques) OR (Maxillary expansion) OR (RME) OR (Rapid maxillary expansion) OR (Rapid palatal expansion) OR (Palatal disjnction) OR (Maxillary disjunction) OR (Maxillary constriction))
OpenGrey	Hearing loss AND Rapid Maxillary Expansion
Google Scholar	Any idiom; Without patents and citations; Classified by relevance; Search;"Palatal Expansion Technique"+"Hearing loss”

APPENDIX 2
References Excluded After Evaluation of Title and Abstract Based on Eligibility Criteria

Reference	Reason for Exclusion
Azeredo F. Avaliação tridimensional das vias aéreas orofaríngeas em pacientes com e sem fissura lábio-palatal submetidos à expansão maxilar. 2014.	Not related to hearing loss evaluation
Baroni M, Ballanti F, Cozza P. Respiratory obstruction syndrome and the rhino-pharyngo-tubal unit. *Mondo Ortodontico*. 2011;36(3):89–105.	Not related to maxillary expansion or hearing loss evaluation
Chrcanovic BR, Custódio ALN. Orthodontic or surgically assisted rapid maxillary expansion. *Oral Maxillofac Surg*. 2009;13(3):123.	Not related to hearing loss evaluation
Conley RS. Evidence for dental and dental specialty treatment of obstructive sleep apnoea. Part 1: the adult OSA patient and Part 2: the paediatric and adolescent patient. *J Oral Rehabil*. 2011;38(2):136–156.	Not related to hearing loss evaluation
Doruk C, Sokucu O, Sezer H, Canbay EI. Evaluation of nasal airway resistance during rapid maxillary expansion using acoustic rhinometry. *Eur J Orthod*. 2004;26(4):397–401.	Not related to maxillary expansion or hearing loss evaluation
dos Anjos Melo K, Costa ST, Stehling RSS, Urbano ES. Risks and complications in surgically assisted rapid maxillary expansion. *RGO*. 2013;61(4):615–619.	Not related to hearing loss evaluation
Farronato G, Giannini L, Galbiati G, Maspero C. RME: influences on the nasal septum. *Minerva Stomatol*. 2012;61:457–465.	Not related to maxillary expansion or hearing loss evaluation
Gremba AP, Weinberg SM, Swarts JD, Casselbrant ML. Craniofacial shape in children with and without a positive otitis media history. *Int J Pediatr Otorhinolaryngol*. 2016;84:110–115.	Not related to maxillary expansion or hearing loss evaluation
Hansen L, Tausche E, Hietschold V, Hotan T, Lagravère M, Harzer W. Skeletally-anchored rapid maxillary expansion using the Dresden distractor. *J Orofac Orthop*. 2007;68(2):148–158.	Not related to maxillary expansion or hearing loss evaluation
Iwasaki T, Yamasaki Y. Relation between maxillofacial form and respiratory disorders in children. *Sleep Biol Rhythms*. 2014;12(1):2–11.	Not related to maxillary expansion or hearing loss evaluation
Kiki A, Kilic N, Oktay H. Slight conductive hearing loss in children with narrowed maxilla and deep palatal vault. *B-ENT*. 2015;11(4):297–301.	Not related to maxillary expansion
Kurt G, Uysal T, Yagci A. Soft and hard tissue profile changes after rapid maxillary expansion and face mask therapy. *World J Orthod*. 2010;11(4):e10–e18.	Not related to hearing loss evaluation
Matthews D. Rapid expansion in clefts. *Plastic Reconstruct Surg*. 1975;56(4):396–401.	Not related to hearing loss evaluation
Mir KP-B, Mir AP-B, Mir MP-B, Moradi-Lakeh M, Balmeh P, Nosrati K. Rapid palatal expansion to treat nocturnal enuretic children: a systematic review and meta-analysis. *J Dent*. 2015;16(3):138.	Not related to maxillary expansion or hearing loss evaluation
Mitsuda ST. Efeito da expansão rápida da maxila assistida cirurgicamente na dimensão nasal. 2008.	Not related to hearing loss evaluation
Oliveira ADS. Avaliação das alterações volumétricas da cavidade nasal decorrentes da expansão rápida de maxila assistida cirurgicamente. 2016.	Not related to hearing loss evaluation
Troester MM, Pelayo R. Pediatric sleep pharmacology: a primer. *Semin Pediatr Neurol*. 2015;22(2):135–147.	Not related to maxillary expansion or hearing loss evaluation
Van Dun B, Verstraeten S, Alaerts J, Luts H, Moonen M, Wouters J. A flexible research platform for multi-channel auditory steady-state response measurements. *J Neurosci Methods*. 2008;169(1):239–248.	Not related to hearing loss evaluation
Aziz T, Ansari K, Lagravere MO, Major MP, Flores-Mir C. Effect of non-surgical maxillary expansion on the nasal septum deviation: a systematic review. *Prog Orthod*. 2015;16(1):1–7.	Not related to hearing loss evaluation
Eichenberger M, Baumgartner S. The impact of rapid palatal expansion on children's general health: a literature review. *Eur J Paediatr Dent*. 2014;15(1):67–71.	Review
Zhang QF, Guo J, Li GF, Zou SJ, Zhao ZH. A potential therapeutic method for conductive hearing loss in growing children-orthodontic expansion treatment. *Med Hypotheses*. 2010;74(1):99–101.	Review
de Souza Lobato IH, Machado SM, Ribeiro SM, Salgado PdA, Pedreira EN. Airway flow and audiologic ability evaluation after rapid maxillary expansion: case report. *Int J Pediatr Otorhinolaryngol Extra*. 2010;5(2):89–90.	Case report
Fingeroth AI. Orthodontic-orthopedics as related to respiration and conductive hearing loss. *J Clin Pediatr Dent*. 1991;15(2):83–89.	Case report
Laptook T. Conductive hearing loss and rapid maxillary expansion: report of a case. *Am J Orthod*. 1981;80(3):325–331.	Case report
Mansan R. O tratamento de deficiência maxilar transversa por meio de expansão rápida da maxila e o consequente comportamento dos sistemas respiratório e auditivo. 2011.	Unpublished review
Aizenbud D, Hefer T, Rachmiel A, Figueroa AA, Joachims HZ, Laufer D. A possible otological complication due to maxillary expansion in a cleft lip and palate patient. *Cleft Palate Craniofac J*. 2000;37(4):416–420.	Syndromic patients on the sample
De Moura CP, Andrade D, Cunha LM, et al. Down syndrome: otolaryngological effects of rapid maxillary expansion. *J Laryngol Otol*. 2008;122(12):1318–1324.	Syndromic patients on the sample