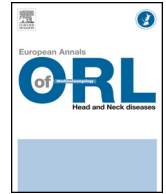




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Review

Pediatric maxillary expansion has a positive impact on hearing? A systematic review and meta-analysis



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ABSTRACT

Objective: Hearing loss is a highly prevalent condition in the pediatric population. Pediatric maxillary expansion is a widespread treatment to address transverse maxillary deficiency. First reports describing an association between improvements for patients with HL and PME initiated in the 1960s. In this systematic review and meta-analysis we aim to review the role of maxillary expansion in reducing conductive hearing loss in pediatric population.

Review methods: Pubmed (Medline), the Cochrane Library, EMBASE and Trip Database were checked. Main outcome was expressed as the difference between air-bone gap, compliance, ear volume and conductive hearing thresholds before and after treatment and the 95% confidence interval.

Results: A total of 10 studies (218 patients) met inclusion criteria. The pooled data in the meta-analysis under a random effects model shows a statistically significant difference of 10.57 dB mean reduction after palatal expansion. The air-bone gap was significantly reduced by 5.39 dB (CI 95% 3.68, 7.10). Compliance and volume were assessed in three studies, with a non-significant positive difference in the compliance (0.14) and a statistically significant difference for volume (0.80) after palatal expansion.

Conclusion: This systematic review and meta-analysis found a positive effect of pediatric maxillary expansion in conductive hearing loss in well-select children. However, results cannot be extrapolated for children with conductive hearing loss without an accompanying orthodontic indication (maxillary constriction). It showed that the existing prospective studies exhibited qualitative pitfalls, limiting the ability to obtain conclusive evidence about the role of pediatric maxillary expansion on conductive hearing loss in children.

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1. Introduction

Hearing loss (HL) is a highly prevalent condition in the pediatric population [1]. The exact etiology of otitis media with effusion (OME) is unknown, however it appears to be multifactorial.

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“Watchful waiting” has been recommended as the first line treatment for OME, while severe and persistent cases are candidates for ventilation tube insertion (grommets) [2].

In 1966, Braun first observed a correlation between HL and maxillary constriction [3,4]. It is one of the most frequent craniofacial skeletal problems, with a prevalence ranging from 2.7 to 23.3% [5].

Pediatric maxillary expansion (PME) is a widespread treatment to address transverse maxillary deficiency, and by consequence improve dentofacial abnormalities, nasal airway and target sleep disordered breathing [6].

First reports describing an association between improvements for patients with HL and PME initiated in the 1960s [3], with the first large case series in 1975, when Gray found that recurrent serous otitis media decreased remarkably in patients who had undergone ME [7]. Since then, several authors have explored the role of maxillary expansion in the outcomes of OME. While the exact mechanism is unknown, it has been suggested that maxillary expansion widens and tense up the elevator and tensor palatini muscles, therefore improving ET function. Furthermore, it has been shown that maxillary expansion decreases nasal resistance in pediatric patients, and as a consequence improved nasal breathing can reduce the occurrence of otitis media [8], at least in due to changes in the microflora of the oropharynx [9], which have shown to reduce the risk of respiratory infections in a clinical trial [10].

In this systematic review and meta-analysis we aim to review the available data and shed some light in the question of the role of maxillary expansion in reducing conductive hearing loss in pediatric population. The main objective is to assess the change in the pure tone audiogram after maxillary expansion in pediatric patients. The secondary objectives are the change in audiogram air-bone gap; the change in ear volume and the change in the ear drum compliance.

2. Methods

This review was performed in accordance with PRISMA guidelines [11], and a formal PROSPERO protocol was published according to the NHS International Prospective Register of Systematic Review (N^o----blinded----) prior to conduct the review. Also, we followed the recommendations of the AMSTAR-2 guideline [12].

2.1. Literature search. Inclusion and exclusion criteria

The criteria for considering studies for the systematic review were based on the population, intervention, comparison, outcome, timing and setting (PICOTS) framework [13].

Participants: pediatric patients up to eighteen years of age.

Intervention: maxillary expansion.

Comparison: pre- and posttreatment data, or treatment and no treatment cohorts (cohorts and clinical trials).

Outcomes: any objective measurement of hearing and tympanogram (audiometry, brainstem auditory evoked potentials).

Timing: without limitation to timing after surgery.

Setting: without limitation to the setting.

Types of studies: clinical trials, case series, prospective and retrospective cohort studies published in peer-reviewed journals. We did not include case reports, thesis or meeting communications. There were no restrictions by date or publication type, and the last update of the search was performed in Feb 2020. We included studies published in English, Spanish, German, French, Italian and Portuguese languages.

Exclusion criteria: exclusion criteria consisted of: (1) studies on syndromic patients; (2) dual publications; (3) studies involving adults without separate analysis for the pediatric sample; (4) articles in which a surgical intervention other than maxillary expansion was performed before the post-intervention hearing evaluation; (5) studies in which hearing evaluation was not performed; (6) studies where hearing evaluation was performed but data was not reported.

2.2. Search strategy

We followed the PRISMA statement recommendations to perform a systematic review, searched Pubmed (Medline), Trip Database, the Cochrane Library, Science direct, SciELO, LILACS, and OpenGrey. We used a predefined search strategy adapted to each

database syntaxis: (“maxillary expansion” OR “palatal expansion” OR “RPE” OR “RME” OR “maxillary disjunction” OR “palatal disjunction”) AND “hearing”. The abstracts of the papers retrieved were thoroughly reviewed by two authors from the Rhinology Study Group of the Young Otolaryngologists of the International Federation of Otorhinolaryngological Societies (CCH, VSP), and those potentially fulfilling inclusion criteria were full-text read. Whenever differences in the judgement of the eligibility, full texts were included for final assessment. We also manually reviewed reference listings of all selected articles to identify works overlooked in the initial search.

2.3. Data extraction, categorization, and analysis

Two authors from the Rhinology Study Group of the Young Otolaryngologists of the International Federation of Otorhinolaryngological Societies (CCH, VSP) analyzed the articles that met inclusion criteria. Variables assessed included sample size, gender, age, indication for treatment, type of expander used, follow-up period and main outcomes. The main outcome was expressed as difference between the variable before and after treatment and the 95% confidence interval. When a control group was available, it was expressed as difference between controls and cases mean. Pure tone audiogram results are expressed in decibels (dB), ear volume in cubic centimeters (cm³) and compliance in decapascals (daPa). If data was missing from a study, the corresponding author was contacted at least twice in an attempt to collect it.

2.4. Assessment of study quality

We assessed the selected articles for both, the level of evidence and quality. Level of evidence was classified according to the Oxford Centre for Evidence-Based Medicine Levels [14]. The risk of bias was assessed according to the Quality Assessment of case series studies checklist from National Institute for Health and Clinical Excellence [15].

2.5. Statistical analysis

All statistical data were analyzed with STATA for Macintosh v. 15.1 (StataCorp[®]). The significance threshold was set at $P < .005$, in line with the movement toward better science supported by the *European Annals of Otorhinolaryngology Head & Neck Diseases*.

Results of non-divisible variables as years and decibels were round to the closest entire value.

We used the Cochrane Collaboration's Review Manager Software (REVMAN) version 5.3 (Nordic Cochrane Centre, Cochrane Collaboration, 2014, Copenhagen, Denmark) to conduct the meta-analysis. The heterogeneity was checked using the Q-test and I² test. A fixed effects model was used when a I² value was < 50%, and a random effects model when it was ≥ 50%. Finally, the publication bias was assessed by a funnel plot and Egger regression.

3. Results

3.1. Search results

A flowchart of the search process appears in Fig. 1. The initial search resulted in 92 publications. After reading all titles and abstracts, 13 studies were selected for full reading. A total of 10 studies (218 patients) met inclusion criteria. Three authors were subsequently contacted twice for additional data, however none of them answered [16–18].

Of papers selected for full-text reading, three publications were excluded for the following reasons: one was performed in

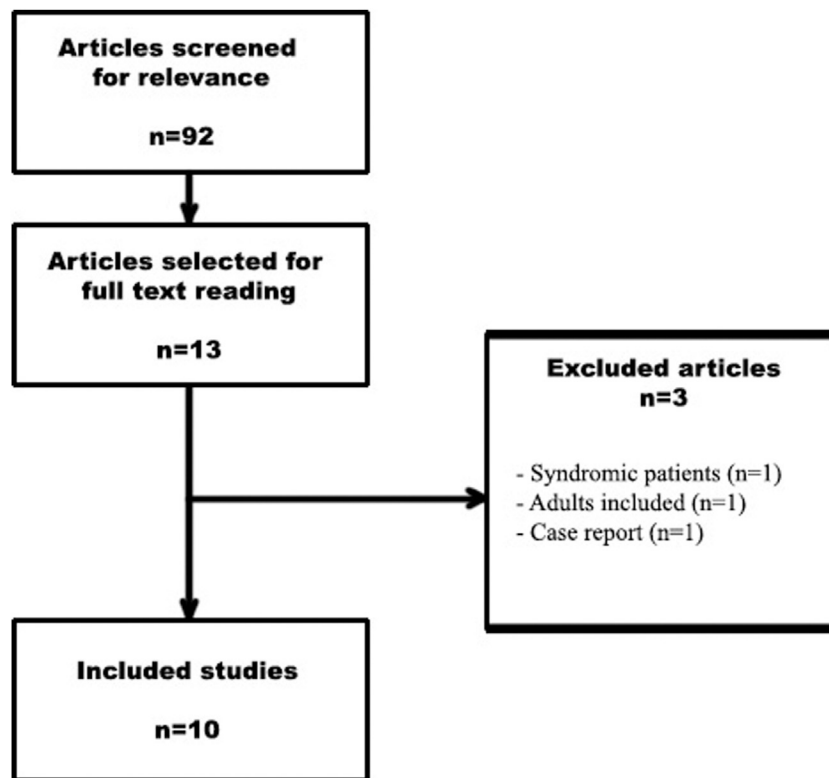


Fig. 1. Flow chart.

syndromic patients [10]; one included adults without subgroup analysis [19] and finally, one was a case report [4].

3.2. Results of the included studies

The median age was 10.5-year-old (Table 1). The lowest mean age was reported by De Stefano et al. [18] and Cozza et al. [20] (7-years-old), the highest by Taşpinar et al. [21] (14-years-old). The youngest child was six-years-old [18,20].

The mean sample size is 21.8 patients (SD 6.75). The largest sample was reported by Taşpinar et al. [21] (35 patients), and the smallest by Ceylan et al. [22] (14 patients).

All articles used rapid expansion protocols, with the exception of Kiliç et al. [23], who used semi-rapid expansion protocol.

3.3. Thresholds

Thresholds were assessed in nine studies. The included studies only assessed hearing by audiometry, none of them used brainstem auditory evoked potentials, and seven provided mean differences and standard deviations. All selected articles found a positive difference after palatal expansion. However, confidence intervals were statistically significant in only five studies. The pooled data in the meta-analysis under a random effects model shows a statistically significant difference of 11 dB mean reduction after palatal expansion (CI 95% 5.21, 15.92) (Fig. 2).

3.4. Air-bone GAP

Changes in air conduction thresholds were assessed in six studies, however mean differences and standard deviation were provided in four. The pooled data in the meta-analysis under a fixed effects model shows a statistically significant difference of

5 dB mean reduction in air-bone gap after palatal expansion (CI 95% 3.68, 7.10) (Fig. 2).

3.5. Compliance and ear volume

Compliance and ear volume were assessed in three studies, but only two could be included in the meta-analysis. The pooled data under a fixed effects model found a positive difference in the compliance (0.14) and volume (0.80) after palatal expansion. The effect was not statistically significant for compliance (CI 95% -0.14, 0.42) but it was for volume (CI 95% 0.60, 1.01) (Fig. 2).

3.6. Long term effects

The mean follow-up period after PME is 13.8 months, when adjusted by sample size. The smallest follow-up interval was performed by Ceylan et al. [22] (4.5 months), and the largest equally by Kiliç et al. [24], Taşpinar et al. [21], and Kiliç et al. [23] (24 months). Four authors found stable results after treatment [21,23–25], while in one improvement was noticed only after 8 months [26], and one demonstrated relapse [22]. Results are summarized in Fig. 3.

3.7. Level of evidence and quality of the included studies

According to the Oxford Center for Evidence Based Medicine classification [14], all included studies are considered level 4. All studies are quasi-experimental, with the exception of Micheletti et al. [17], the only selected cohort study.

3.8. Publication bias

The funnel plot (Fig. 4) and the Egger regression (coefficient -4.48, $P=0.129$) do not suggest a publication bias.

Table 1
Description of the included studies.

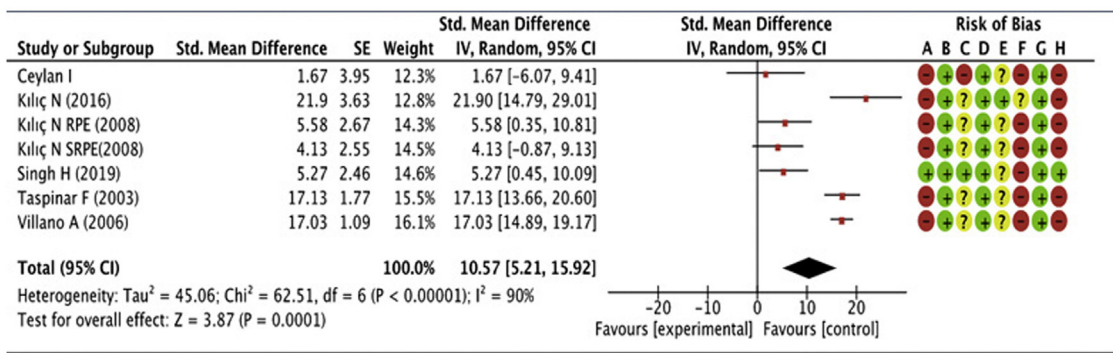
Author (year)	Design/level of evidence	Sample size and sex	Age (years). Mean, (SD), (range)	Indication for treatment	Technique	Main outcome (difference, 95% confidence interval)	ENT selection	Follow-up (months)
Singh H (2019)	Quasi-experimental study/Level 4	26 (11 F, 15 M)	11.1 (\pm 1.8) (9–13)	Bilateral posterior crossbite. No history of previous orthodontic treatment	Appliance: Hyrax Activation: RPE 0.5 mm/day Retention: 3 months. Rigid transpalatal arch 6 months	Threshold (250, 500, 1000, 2000 Hz). (dB) Static compliance (daPa) Middle ear volume (cm ³)	Adenoids: no Rhinitis: yes (excluded) CHL: yes	9
Kılıç N (2016)	Quasi-experimental study/Level 4	15 (8 F, 7 M)	10.07 (\pm 2.72) (6–15)	Maxillary constriction. Deep palatal vault. Bilateral crossbite. Conductive hearing loss. Resistance OME > 3 months	Appliance: Acrylic bonded appliance (10) Hyrax (5). Activation: RPE 0.4 mm/day. Retention: 4 months.	Threshold (250, 500, 1000, 2000 Hz). (dB) (RPE group)	Adenoids: no Rhinitis: no CHL: yes	10
Micheletti KR (2012)	Cohort/Level 4	18 (9 F, 9 M)	8.1 (\pm 3.7) (UK)	Posterior crossbite	Appliance: Haas expander Activation: 0.5 mm/day Retention: UK	Threshold (500, 1000, 2000, 3000, 4000 Hz). (dB) GAP (500, 1000, 2000, 3000, 4000 Hz). (dB) Tympanogram (Herger classification)	Adenoids: no Rhinitis: no CHL: yes	12
Villano A (2006)	Quasi-experimental study/Level 4	25 (15 F, 10 M)	7.24 (\pm 0.58) (6.8–8.2)	Orthodontic reasons (not specified). Recurrent OME and conductive hearing loss	Appliance: UK Activation: 3 times/day Retention: 8 months retainer	Threshold (250–4000 Hz). (dB) Tympanogram (Herger classification)	Adenoids: no Rhinitis: no CHL: yes	8
De Stefano A (2009)	Quasi-experimental study/Level 4	27 (12 F, 15 M)	7 (SD UK) (6–8)	Bilateral posterior crossbite. High palatal vault	Appliance: Hyrax expander Activation: 0.5 mm/day Retention: 3 months	GAP (250–4000 Hz). (dB) Tympanogram (Herger classification)	Adenoids: yes (excluded) Rhinitis: yes (excluded) CHL: yes	12

Table 1 (Continued)

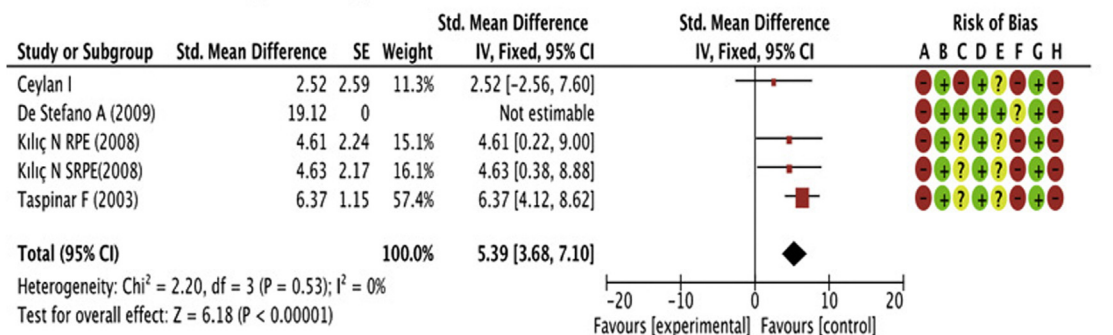
Author (year)	Design/level of evidence	Sample size and sex	Age (years). Mean, (SD), (range)	Indication for treatment	Technique	Main outcome (difference, 95% confidence interval)	ENT selection	Follow-up (months)	
Kılıç N (2008)	Quasi-experimental study/Level 4	19 (14 F, 5 M)	13.5(±1) (12–14.9)	Severe maxillary width deficiency, bilateral crossbite, and deep palatal vault	Appliance: Acrylic bonded Activation: semirapid (not explained). Retention: 6 months and rigid transpalatal arch 2 years	Threshold (250, 500, 1000, 2000 Hz) (dB). GAP (500, 1000, 2000 Hz) (dB) Static compliance (daPa) Middle ear volume (cm ³) 4.13 (–0.86; 9.12) 4.63 (0.37; 8.90) 0.14 (–0.21; 0.48) 0.73 (0.50; 0.96)	Adenoids: no Rhinitis: no CHL: no	24	
Kılıç N (2008)	Quasi-experimental study/Level 4	15 (12 F, 3 M)	13.43 (±0.86) (11.25–14.83)	Severe maxillary width deficiency, bilateral crossbite, and a deep palatal vault	Appliance: Acrylic bonded appliance Activation: RME twice a day, until adequate expansion was achieved Retention: 6 months and rigid transpalatal arch 2 years	Threshold (250, 500, 1000, 2000 Hz). (dB). GAP (500, 1000, 2000 Hz). (dB). Static compliance (daPa) Middle ear volume (cm ³) 5.58 (0.36; 10.81) 4.61 (0.23; 9.00) 0.135 (–0.37; 0.64) 1.05 (0.62; 1.47)	Adenoids: no Rhinitis: no CHL: no	24	
Cozza P (2007)	Quasi-experimental study/Level 4	24 (8 F, 16 M)	7 (SD UK) (6–8)	No adenoidal blockage. OME and conducted hearing loss	Appliance: Butterfly expander Activation: RPE 3 times/day. Retention: 6 months	Audiometry thresholds Tympanogram (Herger classification)	Descriptive data, no SA Before: 12 patients conductive hearing loss. 12 light conductive hearing loss After: 23 normal. 1 light conductive hearing loss Descriptive data, no SA Before: 4 A, 10 B, 8 C, 2 As, 0 Ad After: 18 A, 0 B, 1 C, 3 As, 2 Ad	Adenoids: yes (excluded) Rhinitis: no CHL: yes	24
Taşpinar F (2003)	Quasi-experimental study/Level 4	35 (21 F, 14 M)	14.6 (SD UK) (13–16)	Maxillary constriction and high palatal vault	Appliance: Hyrax Activation: RPE 3 times/day 3 days then 2/day Retention: 6 Months. Rigid transpalatal arch 2 years	Threshold (250, 500, 1000, 2000 Hz). GAP (250, 500, 1000, 2000 Hz). 17.13 (13.66; 20.59) 6.37 (4.12; 8.62)	Adenoids: no Rhinitis: no CHL: no	24	
Ceylan I (1996)	Quasi-experimental study/Level 4	14 (11 F, 3 M)	12.11 (±1.9) (10.4–16.9)	Maxillary width deficiency, deep palatal vault	Appliance: Hyrax Activation: RME 0.6 mm/day 3 days, 0.4 mm/day Retention: 4.5 months	Threshold (250, 500, 1000, 2000 Hz). (dB). GAP (250, 500, 1000 Hz). (dB). 1.67 (–6.08; 9.42) 2.52 (–2.56; 7.61)	Adenoids: no Rhinitis: no CHL: no	24	

UK: unknown; SSD: statistically significant differences; SA: statistical analysis; PTA: pure tone audiogram; Hz: hertz; ME: rapid maxillary expansion; CHL: conductive hearing loss; dB: decibel.

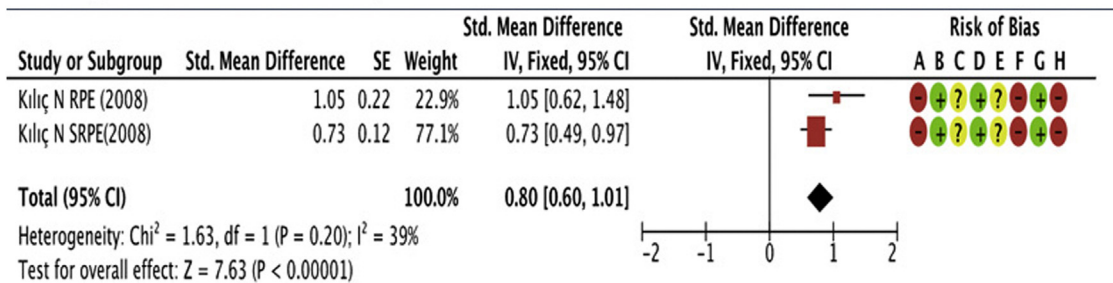
Audiometry thresholds



Audiometry Gap



Impedanciometry volume



Impedanciometry compliance

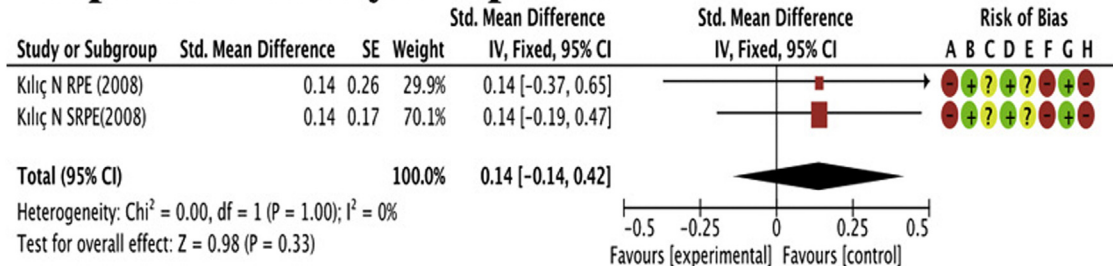


Fig. 2. Forest plot.

4. Discussion

There has been prior extensive reviews about this topic [27–29]. However, this study is the first meta-analysis assessing the role of maxillary expansion on conductive hearing thresholds in pediatric patients. Also, different from previous reviews, in this study the results from pure tone audiogram, air-bone GAP, compliance and ear volume were independently assessed.

In this systematic review and meta-analysis, maxillary expansion in the pediatric population has been shown to significantly reduce conductive hearing thresholds by 10 dB and audiometric air-bone GAP by 5 dB.

The method utilized to assess hearing show heterogeneity in reported results. Some authors present their result as changes in the audiometric GAP, others only in thresholds, however most have used both.

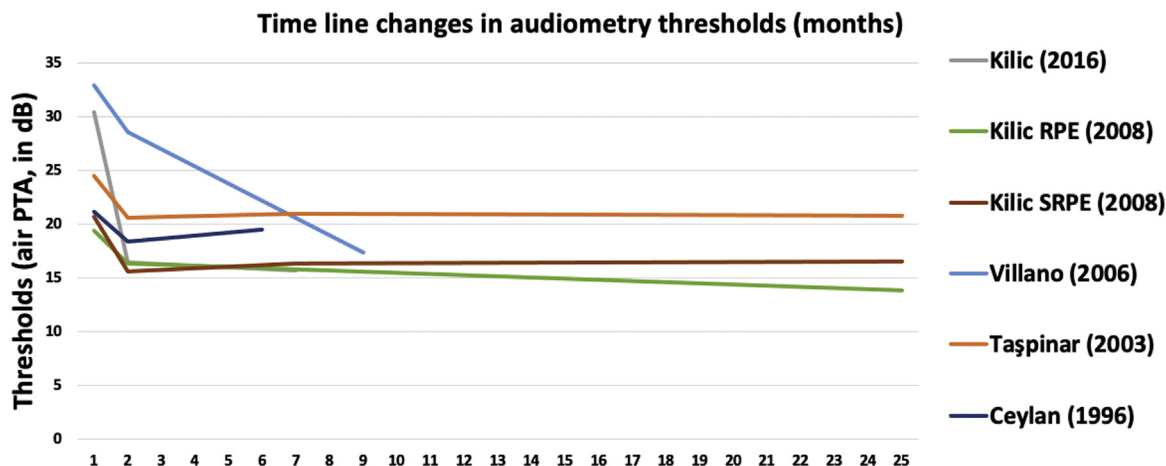


Fig. 3. Time-line.

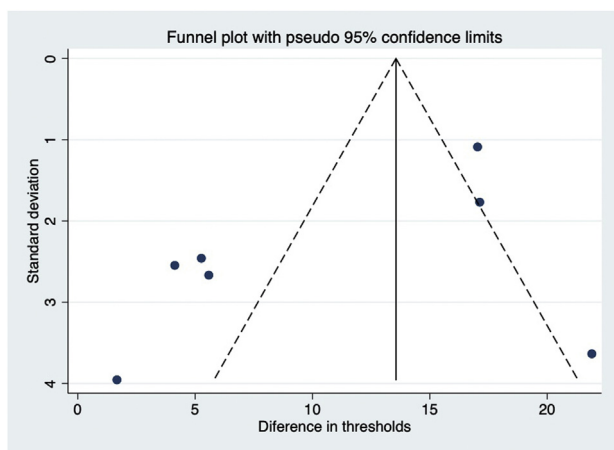


Fig. 4. Funnel plot.

There were significant differences in audiometric frequencies used by different authors. Most authors selected 250, 500, 1000 and 2000 Hz [16,21–25], while some excluded or added additional frequencies [17]. Only Villano et al. [26] and De Stefano et al. [18] included all the frequencies between 250 to 4000 Hz.

There is variability in frequencies tested even within the same study. Ceylan et al. [22] chose four frequencies for thresholds, but only three (excluded 2000 Hz) for the audiometry air-bone gap. Similar findings were observed in the work of Kiliç et al. [23,24], which excluded 250 Hz frequency for air-bone gap. Cozza et al. [20] did not present tested frequencies, instead, their results were categorized. Authors who used only lower frequencies justified it as conductive hearing loss due to OME primarily affects that range. However Villano et al. [26] found statistically significant changes in high frequencies as well, suggesting that while conductive HL due to OME affects predominantly low frequencies, the whole audiogram should be performed as valuable information about high frequency HL can be overlooked.

In relation to tympanogram studies, maxillary expansion in children was followed by a significant 0.80 cm³ mean increase in ear volume assessed by impedanciometry after treatment. Changes were not significant for ear drum compliance.

Seven authors performed tympanogram; however, results were reported differently. The same three authors who published changes in compliance [16,23,24], presented alterations in ear volume, while four presented it as a categorical variable following the Herger classification [17,18,20,26].

While most selected authors hypothesize that changes in middle ear function after PME are explained by improvement in the ET function, none objectively assessed its permeability.

The main limitation of the included studies is the lack of a proper control group. The presence of a control group is of utmost importance, considering the natural course of self-resolution and improvement in Eustachian tube function and hearing in some OME patients [2]. None of the selected papers present a matched control group. This is a major limitation, which makes impossible to obtain any solid conclusion with the available evidence.

Three authors included unmatched controls. Kiliç et al. [25] included patients without conductive hearing loss, Singh et al. [16] included patients with bilateral cleft palate, and finally, Micheletti et al. [17] described a control group without OME and hearing loss.

Only one study on this topic had an appropriate control group, however it was not included in this systematic review as it was performed in Down’s syndrome patients [10]. In this article both groups had improvement in hearing loss, however there were statistically significant differences favoring rapid maxillary expansion group.

All papers failed to control for significant confounding factors. First age, as the ET and intermaxillary suture maturation vary with age. Authors included patients with a wide age range without subgroup analysis, preventing an adequate data pooling. Also, the youngest included child was six-years-old, which introduces an important bias, as there is no information in younger children who are usually most severely affected by persistent OME.

Patient selection may be the most important issue on analyzed papers. As previously emphasized by Timms [24], these studies were performed in children selected to PME for dento-facial indications, with or without unreported conductive hearing loss. For example, Micheletti et al. [17] did not find differences after treatment, however, the median threshold both before and after treatment was only 5 dB. It means that children had an appropriate conductive hearing before expansion, without margins for improvement after maxillary expansion.

Six of ten included papers evaluated patients with OME and conductive hearing loss [16–18,20,25,26]. Cozza et al. [20] specifies that they selected patients with OME and conductive hearing loss, without adenoid hypertrophy. However, half of their sample had minor hearing loss, and only 10 of 24 patients had a flat tympanogram. This fact has been previously explored by Timms [30], who pointed out that the selected sample had a large number of patients without OME, therefore not expected to present hearing changes.

The association of adenoid hypertrophy and rhinitis with OME is well described [31]. Ideally, patients suffering with OME

undergoing PME should have treatment for rhinitis and significant adenoid hypertrophy, or for investigation purposes been identified to perform a subgroup analysis. Only De Stefano et al. [18] performed this detailed evaluation. Cozza et al. [20] excluded patients with adenoid hypertrophy only, without mention to rhinitis.

Although there are numerous reports on short-term effects of PME on conductive hearing loss, there is scarcity of information on long-term results. This is the first review to provide a timeline graphic (Fig. 3). Only Ceylan et al. [22] found relapse after ME, however as pointed out by Timms, selection bias and lack of appropriate control for confounding factors are likely to explain it [30].

There are no studies comparing different appliances or activation protocols. Kiliç et al. [25] (2016) used different types (hyrax and acrylic bonded), however they did not perform a subgroup analysis. Kiliç et al. [24] (2008) attributed their results at least in part to the type of device and schedule used for the expansion protocol.

The amount of expansion and retention times varied among selected papers as well. The amount of expansion may be influenced by the severity of the maxillary constriction and the degree of expansion obtained, however none of authors adjusted their results by these factors.

Semi-rapid maxillary expansion (SRME) and slow maxillary expansion have some advantages, such as less relapse tendency and more physiologic results [32]. However, it has been suggested that SRME causes less effect on the intermaxillary suture. The only paper who used semi-rapid maxillary expansion is Kiliç et al. [23], with positive effects, however the confidence interval was not statistically significant.

Finally, as with any systematic review, we may have missed studies in the literature despite our best efforts.

5. Conclusions

This systematic review and meta-analysis found a positive effect of pediatric maxillary expansion in conductive hearing loss in well-select children. However, the main limitation is the lack of control group. Given the self-improvement of OME, this limitation makes impossible to obtain any solid conclusion. The importance of this study is not to directly take conclusions from it, but to guide future research. Secondly, results cannot be extrapolated for children with conductive hearing loss without an accompanying orthodontic indication (maxillary constriction). It showed that the existing prospective studies exhibited qualitative pitfalls, limiting the ability to obtain conclusive evidence about the role of pediatric maxillary expansion on conductive hearing loss in children. Future studies should have larger samples, control groups and detailed evaluation for confounding factors.

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Disclosure of interest

The authors declare that they have no competing interest.

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