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Research Article

"Effects Of Rapid Maxillary Expansion On Speech Sound Production In Growing Patients. A Systematic Review"

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ABSTRACT

One common orthodontic supplement treatment for posterior cross-bites is the use of rapid palatal expanders. Rapid palatal expanders could make it difficult for the tongue to move freely and make adequate linguo-palatal contact. This review study aimed to ascertain the precise effects of rapid palatal expanders on the development and production of speech sounds in children and young adolescents who have undergone this type of orthodontic intervention.
Clinical studies evaluating patients with maxillary transverse deficiency who had orthodontic treatment and the association with speech changes without limiting

language or year of publication. There were only interventional studies included. RME changed the fundamental frequency of vowels and the formant frequency of fricative phonemes, which affected speech output. In one study, shimmer rate was altered, while in two experiments, jitter rate was altered. In two investigations, speech deteriorated during orthodontic treatment, but improved once the appliances were taken out. RME has an impact on speech both during and after treatment, despite the few data. Few research have looked at this matter in the literature; those that have often found a short-term, detrimental effect on some speech sounds within two weeks of the expanders being placed. More research is required because there is currently a lack of scientific understanding on the long-term effects and the effect on a wider variety of speech sound categories.

Keywords: rapid maxillary expansion, speech, voice

1. INTRODUCTION

Voice production is controlled and regulated by almost 100 muscles distributed through the chest, abdomen, head, and neck. The formation of voice production involves three main functional systems: Respiratory, laryngeal, and supralaryngeal. The spoken word in its original form is generated by air pressure variations.[1]
The larynx produces a spectrum of sound frequencies that are shaped and modulated by resonances within the vocal tract structures among which is the maxillary arch.[2]
Sounds in American English could be grouped into two categories: Consonants and vowels. Consonants are differentiated from vowels based on the extent to which the articulators cause airway constriction. That results in much more consonant articulation defects than vowels.[3]
The most prominent acoustic properties of vowels are formants. They are high energy regions and seen as dark bands on a spectrogram. Although there are five formants for each vowel, the first two are the most prominent indicators of vowel quality. Formants are abbreviated as F1 (first formant), F2 (second formant), etc. Any anatomic change in the vocal tract impacts on speech production if it alters resonating cavities, the shape, and the size of the articulators.[4]
While voiceless fricatives are produced by altering a turbulent source of noise, vowels have distinct bands of acoustic frequencies called formants. Usually, the centre frequencies of these formants are used to discreetly acoustically describe a vowel .[5]
In orthodontics, rapid maxillary expansion, or RME, is a popular and successful treatment that can expand palate volume by up to 21% without significantly changing the height of the palatal vault. By altering the tongue's articulation locations on the palate and expanding the oral cavity, these notable alterations in palatal morphology may have an impact on speech. Vowel sound alteration is caused by maxillary surgical

enlargement, and proper speech pronunciation is correlated with palate size. Consonant and vowel articulation are changed when fixed components are introduced into the oral cavity, such as an artificial palate or orthodontic appliances.[6]

It is known that any change in the shape or volume of the anatomic units forming the vocal tract may affect the structure of the sound.[7] Numerous studies have demonstrated that after orthognathic surgery, alterations in the jaws' sizes, locations, and angles may result in modifications to the tongue's position and velopharyngeal function, which may have an impact on the patients' articulation and speech characteristics.[8-11] Other research revealed that the impacts of sex hormones and larger anatomical units lead the vocal tract to expand during puberty, causing abrupt changes in voice.[12-13] A spectrogram is a graphic depiction of sound frequencies used in acoustics. High-energy regions that appear as dark bands on spectrograms are known as formant frequencies. It is common and useful to define the acoustic properties of vowels in comparison to other sounds during sound analysis.[14] Even though each vowel has five formants, only the first three are necessary to define a single vowel. The tongue moves, becoming more anterior in position as a result of fast maxillary expansion.[15]Thus, it is assumed that maxillary expansion affects formant frequencies characteristic. The aim of this systematic review was to evaluate the voice changes after maxillary expansion.

2. MATERIALS AND METHODS

Research question and eligibility criteria

The research question, "Can rapid maxillary expansion affect speech sound production during or after treatment in orthodontic patients?" was formulated using the PICO acronym (Population, Intervention, Comparator, and Outcome) (Table 1). Studies were selected according to the eligibility criteria. (Table 2)

TABLE 1	
PICO FORMAT	
Population	Studies including growing orthodontic patients with maxillary transverse deficiency (age cutoff of 19 years), irrespective of the type of dentition (permanent or mixed).
Intervention	All types of Nonsurgical Rapid Palatal Expansion Methods
Comparison	The same patients before, during, and after the expansion therapy, or a control group that received no treatment
Outcome	Effects of sound production by maxillary expansion in terms of jitter, shimmer, fundamental (F0) and formant (F1, F2, F3, and F4) frequencies, and pronunciation clarity

Eligibility criteria for study selection (Table 2):

TABLE 2	
1. Types of studies	• Retrospective or prospective, randomized or non-randomized controlled/un-controlled trials before and after. • Experimental, clinical studies effects of dental and skeletal changes caused by maxillary on vocal quality were investigated
2. **Participants**	• Children and Adolescents With class I, II or class III malocclusion with/without posterior crossbite or OSA, undergoing RPE treatment for the correction of transverse maxillary deficiency/constricted maxillary arches.
3. **Intervention**	• R apid palatal expansion with any expander design (bone anchored, tooth-anchored or tooth-bone anchored) • Voice recorded on microphones and analysed using software.
4. **Outcome measure**	After expansion therapy, voice quality differences measured • Clinically

The goal of the current systematic review was to answer the question " Can rapid maxillary expansion affect speech sound production during or after treatment in orthodontic patients?" by defining the eligibility criteria using the Population, Intervention, Comparator, and Outcome (PICO) approach. Exclusion criteria for the study was(a) studies examining only patients with craniofacial anomalies, including cleft lip, cleft palate, or both (b) studies including only patients with speech difficulties(c) studies involving extraction of permanent tooth before orthodontic treatment or any other maxillary intervention associated with rapid expansion (d) review articles, letters to the editor/editorials, personal opinions, book chapters/ books, textbooks, reports, congress abstracts, and case reports/ series

Information sources and search

The MEDLINE (via PubMed), SciELO, Scopus, and Web of Science electronic databases were the primary study sources. Also, the reference lists of eligible studies were analysed. Subject headings were searched in MeSH (Medical Subject Headings) terms. The Boolean operators 'AND' and 'OR' improved the search strategy, respecting the syntax rules of each database. The bibliography was searched until February 2023 without publication year or language restrictions.

Study selection

Article selection comprised three stages. The obtained study registries were exported to Microsoft Word (Microsoft™, Ltd) to eliminate duplicates manually. The titles and abstracts of all studies were read and maintained or excluded according to the inclusion and exclusion criteria. Then, the full texts of articles included after abstract analyses were read, determining the final selection. One calibrated reviewers (AAD) independently performed this process. A second reviewer (SKG) solved any disagreement. The studies removed in the full-text reading phase were registered separately, indicating the reasons for exclusion.

Data collection and extraction

After selection the data was extracted using specific worksheets for data extraction. The following information was gathered: article identification (author, year of publication, and country of study performance); sample characteristics (the number of patients in each study and their mean ages); phonemes assessed; period of speech articulation analysis; type of intervention; activation protocol; method of speech articulation analysis; pre- and post-treatment results; and main outcomes.

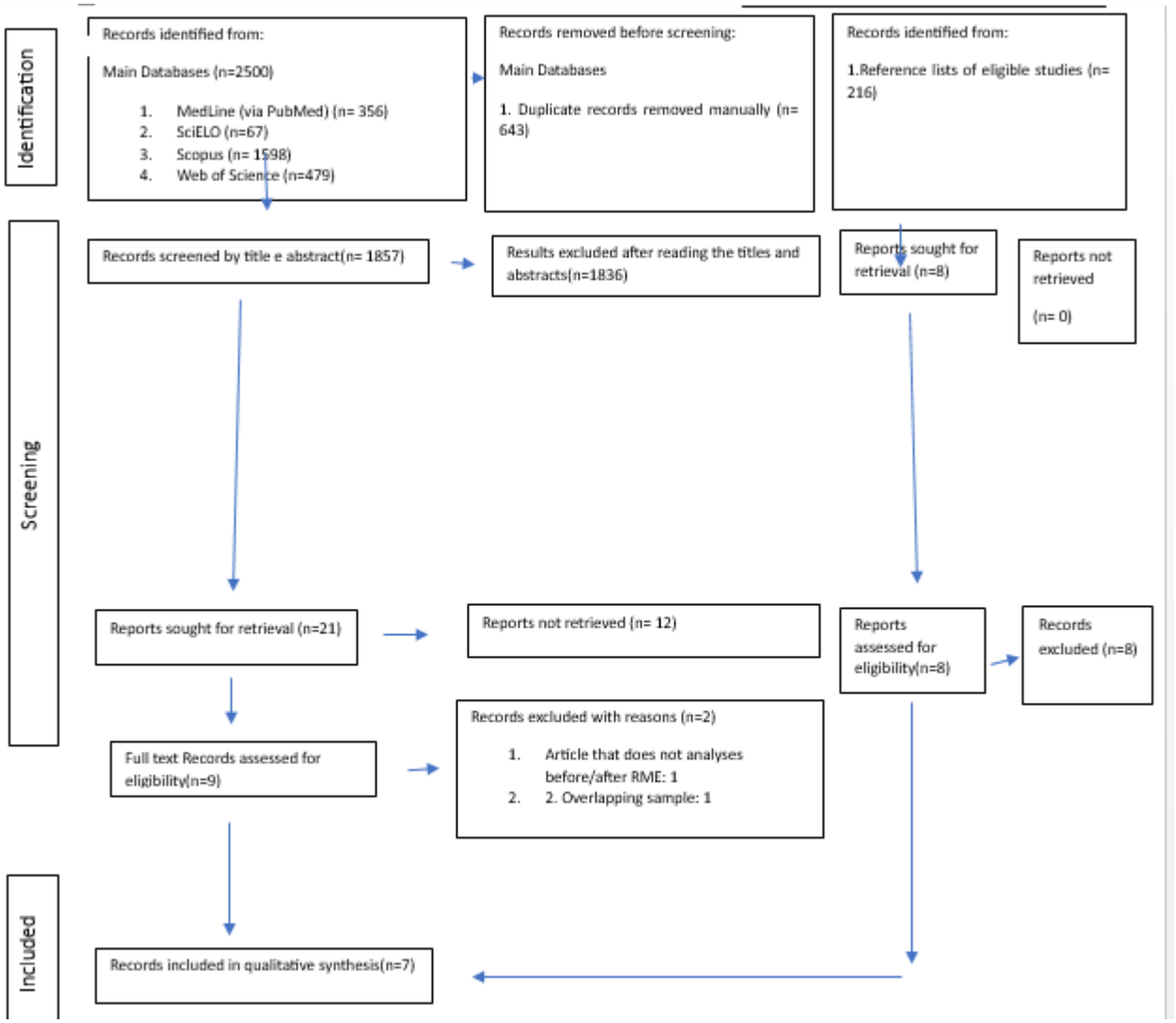

Figure 1- Flow Chart for Study Selection Process

3. RESULTS

After a thorough search of electronic databases,356 studies were retrieved from PubMed, 1598 from Scopus, 67 from SciELO and 479 from Web of Science. After application of the initial inclusion and exclusion criteria and elimination of studies indexed in more than 3 database, 21 were retrieved. The full texts were accessed, studies irrelevant to this systematic review were excluded. Ultimately, 7 articles that fulfilled all inclusion and exclusion criteria were included in this systematic review. (Figure 1)

Author, year	Country	Sample (n)	Mean age	Phonemes assessed	Type of intervention	Activation protocol
Stevens et al.,[16] 2011	Canada	Normal speech (n = 12) and speech difficulties (n = 10) 13 females 9 males	9–19 14 years	Vowel /i/ and fricatives /s/ and /ʃ/	Orthopaedic (Hyrax expander – banded or bonded)	Not reported
Macari et al.,[2] 2016	Lebanon	7 females 7 males	8–15 11.64 ± 1.69 years	Vowels /a/, /i/, /o/, and /u/.	Orthopaedic (Hyrax)	Not reported
Yurttadur et al.[17], 2017	Turkey	Expansion group: 14 females; 6 males Control group: 13 females; 7 males	12–17 Expansion group: 14.16 years Control group: 14.4 years	Vowel /a/	Orthopaedic (modified McNamara expander)	One-quarter turn 2x a day for 1 week. Activation was reduced to 1/4 turn once a day after the suture had opened radiographically.
Biondi et al.,[6] 2017	Italy	21 females 14 males	7–14 9.3 ± 2.3 years	Fricatives /s/ and /ʃ/, palatal /ɲ/ and /ʎ/, and vowel /i/	Orthopaedic (Hyrax expander – two arms and four arms)	One-quarter turn a day until contact of the palatal cusp of the upper first molar with the buccal cusp of the lower first molar.
Bilgiç et al.,[18] 2018	Turkey	16 females 14 males	9–13 12.01 ± 0.75 years	Vowel /a/	Orthopaedic (Hyrax expander)	One-quarter turn (0.25 mm per turn) 2x a day until suture had opened radiographically and continued up to 2–3 mm of overexpansion. The same appliance was used as a passive retainer
Güleç et al.[19], 2019	Turkey	4 females 2 males	12–16 13.68 ± 1.4 years	Vowels /a/, /ɛ/, /ɯ/, /i/, /ɔ/, /œ/, /u/, and /y/	Orthopaedic (acrylic captype Hyrax expander)	One-quarter turn a day until contact of the palatal cusp of the upper first molar with the buccal cusp of the lower first molar
Singh et al.,[20] 2021	India	Non-cleft 11females 15males Cleft 13females 14males	9–13 11.1 ± 1.8 years	Vowel /a/	Orthopaedic (bonded Hyrax expander)	One-quarter turn twice a day – one turn in the morning and one in the evening – between 7 and 14 days until complete elimination of posterior crossbite.

Table 3- Summary of the main characteristics of the studies selected for qualitative analysis

A summary of the studies' key features is shown in Table 3. A total of 200 people were included in the analysis (112 women and 88 males). The age range was seven to nineteen.

In one study, patients who had previously struggled with speaking were compared to patients who spoke normally.[16] One study included patients with cleft and non-cleft.[20] One study[17] used the modified Mc Namara expander and rest 6 included[16,2,6,18,19,20] the HYRAX type of expander. All research had different access techniques for speech sound production adjustments; the only thing they had in common was the recorded voice for evaluation.

Ten native listeners who were unaware of speech treatment or the study's goals assessed the patients' recordings for pronunciation clarity using a Likert scale
The lowest acceptance scores were found by Stevens et al.[15] 15 minutes after the device was placed. Speech acceptability, however, quickly returned to its baseline level upon the removal of the device and improved over time. Additionally, the acceptance scores were much higher than before treatment in the most recent assessment, which was conducted 1-2 months after the appliance was removed. The speech patterns of patients with pre-existing speech impairments and those with normal speech did not differ significantly. Similar findings were made by Biondi et al.[6] in their investigation. After RME, acceptance scores declined significantly. Thereafter, they gradually improved and returned to baseline values in the most recent evaluation, which was conducted two months after the appliance was removed.

Quality assessment was done to classify the included studies into High, Medium or Low- quality studies (Table 4). After quality assessment, 1 study was classified as high quality and 6 studies as medium quality

It was observed that, most of the studies performed were uncontrolled clinical trials. Additionally, the voice assessment parameters taken in the performed studies were variable.

Majority of the articles concluded that the amount and success rate of skeletal expansion was inversely proportional to the age of the subject and the mid-palatal suture maturation.

TABLE 4: Assessment of Quality of the studies

S.no.	Study	Study design	Sample size	Sample description	Method error analysis	Adequacy of statistical	Quality score	Study quality
		0-3	0-1	0-2	0-1	0-2	0-9	
1	Stevens et al[16]., 2011	1	1	2	1	1	6	Medium
2	Macari et al., 2016[2]	1	0	2	1	1	5	Medium
3	Yurttadur et al., 2017[17]	1	1	2	1	1	6	Medium
4	Biondi et al., 2017[6]	1	1	2	1	1	6	Medium
5	Bilgiç et al., 2018[18]	1	1	2	1	1	6	Medium
6	Güleç et al., 2019[19]	1	1	2	1	2	7	High
7	Singh et al., 2021[20]	1	1	2	1	2	7	High

The risk of bias in the chosen studies was evaluated using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (non-randomized experimental research). Nine questions make up this tool, and the answers are "yes," "no," "unclear," or "not applicable.""
There was only one study[2] that included a control group and did not compare the participants in any way. Every other factor that assessed methodological quality was mentioned in the research. Table 5 provides comprehensive data regarding bias risk.

Sr No	Study	Clarity about cause and effect?	Were participants included in any similar comparison?	Were the participants receiving similar care in comparison group?	Was there a control group?	Multiple measurements of the outcome both before and after the intervention/exposure?	Was follow-up complete?	Outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?
1	Stevens et al., 2011	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
2	Macari et al., 2016	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
3	Yurttadur et al., 2017	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	Biondi et al., 2017	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
5	Bilgiç et al., 2018	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
6	Gülec et al., 2019	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
7	Singh et al., 2021	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

Table 5-Risk of Bias

4. DISCUSSION

The association between quick palatal expanders and speech production has only been the subject of a relatively small number of research to date. A retrospective questionnaire was administered to 165 patients undergoing different designs of fixed fast palatal expanders as part of a study conducted by De Felippe et al[21]. Regardless of the type of expander, almost 89% of patients said that, in the first week following cementation, the expander had an impact on their ability to speak. Determining the specific phonetic sounds and degree of speech impairment was challenging, though. After a week, most patients claimed to themselves that their speech had returned to normal, which shows a remarkable level of appliance adaption. Furthermore, the variables were unaffected by factors related to gender or age.[21]

22 individuals who had Hyrax or bonded type expanders had altered speech, according to another more clinically based study by Stevens et al.[16] Six time points were recorded in speech: prior to the expander's placement, during its insertion, during expansion, during retention, following its removal, and four weeks later. Ten native undergraduate students evaluated speech acceptability, and the vowel sounds /s/, /ʃ/, and /i/ were subjected to an acoustic study. Speech was generally changed and distorted once the device was initially installed. With time, the patient's speech improved progressively, reaching baseline once the device was taken out.

It was thought that the generation of speech sounds was somewhat influenced by these three noises. The impacted vowel, /i/, displayed a notable rise in F1 from T1-T2 38 and a drop in F2 from Time 1 (before expander insertion; T1) to Time 2 (immediately after cementation; T2). Additionally, they discovered notable aberrations when spectral moments for /s/ and /ʃ/ were examined. It took two to four weeks after implantation for adaptation to reach baseline levels.[16]

Perceptual analysis was used in the previous two investigations [16] to rate the degree of speaker impairment on a scale; however, this method has limitations in terms of accuracy and reliability [22-23]. The effects of the palatal expander on individual phonemes could be evaluated more objectively thanks to the use of an acoustic technique to data processing.

likelihood of voice modifications occurring right away following appliance implantation in the oral cavity increases with its bulk. With the device remaining in place, Stevens et al. [16] and Biondi et al. [6] measured alterations during RME. In both trials, articulation declined within the first month of treatment, demonstrating a direct correlation between changes in oral cavity capacity and changes in speech.

The frequency and amplitude of speech sounds are correlated with jitter and shimmer rates, respectively.[24] According to these acoustic characteristics, there are variations in voice quality[19,20], and diseased voices typically exhibit more jitter.[25] Jitter and shimmer were analysed in four studies [16,17,18,20]. Macari and associates, [2]

Both Singh et al. [20], and Bilgiç et al.[18], demonstrated enhanced shimmer and reduced jitter. There were no discernible changes in the jitter and shimmer measures, according to Yurttadur et al.[17]

The limitations in the included research should be carefully taken into account when interpreting the reported results. Given the tight relationships between formant frequencies and the anatomy of the larynx, vocal tract, tongue height, and soft palate position, one could argue that one component of sample heterogeneity is concerning. Due to the fact that men have lower fundamental frequencies than women, ages would not be equivalent.[26] The linguistic diversity of the included research is a noteworthy constraint on the current body of evidence. Given that different languages employ varied perioral musculature, intonation, and articulation techniques for the identical vowels and phonemes, this information is pertinent to take into account when evaluating the findings of research that meet the eligibility requirements.

The current systematic review, however, is unique in that it is the first to confirm if RME has an impact on speech. The review's findings supports the need of giving patients and their families guidelines. Discomfiture complaints and speech articulation problems, including as distortions in vowels, linguodental sounds, and fricatives, are common shortly following device placement. There may be lingering distortions, like fricative sounds, for around three months even after the equipment is removed.[27] The orthodontist should assess whether the patient's speech alterations continue upon their return, and if so, a referral to a speech therapist is necessary.

5. CONCLUSION

We can infer that many phonemes can be warped upon the expander's placement, which specified altered speech sound output, based on the very small number of studies in the literature about the impact of palatal expanders on sound production. Speech takes more than two weeks to recover to baseline for most phonemes, if it does so at all. other phonemes, a longer study period, and a larger sample size might be used in future studies to examine other potential affecting factors.

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