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The effect of rapid maxillary expansion on the upper airways morphological and functional characteristics

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Abstract

Background and Objectives. It is noticed that rapid maxillary expansion (RME) is not only an effective treatment for correcting transverse orthodontic anomalies but its advantages to the upper airway are reported too. This systematic review aimed to evaluate nasopharyngeal and oropharyngeal volumetric changes and their correlation with skeletal and dental measurements after RME treatment.

Methods. This systematic review followed the PRISMA guidelines. The literature search was conducted using PubMed Cochrane Library, and Science Direct electronic databases. Data assessing changes in upper airway characteristics after RME treatment evaluated with cone beam computed tomography (CBCT) was extracted, and quality of the studies was assessed.

Results. A total of 278 articles were identified in the electronic database. After applying selection criteria 9 studies were included in this systematic review. According to the Newcastle-Ottawa Scale (NOS), all included articles were graded as “Good” quality. The controversial results were observed regarding nasopharyngeal volume changes after RME. The volume of oropharynx increased after RME, however, only two of five authors found this result being statistically significant. Improved apnea/hypopnea index **(**AHI) and better oxygen saturation by 5 % were reported in three studies. It was calculated that maxillary width expansion by 1mm leads to oropharyngeal volume enlargement from 363.7 to 1571.0 mm^3, as well as the intermolar width increasement by 1mm raises oropharyngeal volume from 439.0 mm^3 to 997.2 mm^3.

Conclusion. RME treatment tends to increase oropharyngeal volume and improve respiratory performance. However, the findings should be interpreted with caution due to heterogeneity of the included studies and further research is needed for more reliable conclusions.

Keywords. Rapid maxillary expansion, upper airways, morphology, functional characteristics, systematic review

Greito viršutinio žandikaulio plėtimo įtaka viršutinių kvėpavimo takų morfologijai ir funkcijai

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Santrauka

Įvadas. Pastebėta, kad greitas viršutinio žandikaulio plėtimas (RME) yra ne tik veiksminga gydymo priemonė transversalinėms ortodontinėms anomalijoms koreguoti, bet ir turi teigiamą poveikį viršutiniams kvėpavimo takams. Šios sisteminės apžvalgos tikslas - įvertinti nosiaryklės ir burnaryklės tūrinius pokyčius ir jų koreliaciją su skeletiniais ir dentaliniais parametrais po greito viršutinio žandikaulio plėtimo gydymo.

Metodika. Ši sisteminė apžvalga atlikta vadovaujantis PRISMA gairėmis. Literatūros paieška atlikta iki 2024 m. sausio 10 d., naudojantis PubMed Cochrane Library ir Science Direct elektroninėmis duomenų bazėmis. Buvo atrinkti tyrimai, vertinantys viršutinių kvėpavimo takų charakteristikų pokyčius po RME gydymo, naudojant kūginio pluošto kompiuterinę tomografiją (KPKT), ir įvertinta tyrimų kokybė.

Rezultatai. Iš viso elektroninėje duomenų bazėje buvo rasti 278 straipsniai. Pritaikius atrankos kriterijus, į šią sisteminę apžvalgą įtraukti 9 tyrimai. Pagal Newcastle-Ottawa skalę (NOS) visų įtrauktų straipsnių kokybė buvo įvertinta kaip "gera". Prieštaringi rezultatai gauti vertinant nosiaryklės tūrio pokyčius. Burnaryklės tūris po greito viršutinio žandikalio plėtimo gydymo padidėjo, tačiau tik du iš penkių autorių įvertino šį rezultatą kaip statistiškai reikšmingą. Apie pagerėjusį apnėjos/hipopnėjos indeksą (AHI) ir 5 proc. geresnį deguonies įsotinimą pranešta trijuose tyrimuose. Taip pat apskaičiuota, kad viršutinio žandikaulio pločiui padidėjus 1 mm, burnaryklės tūris padidėja nuo 363,7 iki 1571,0 mm^3, o 1 mm padidėjus pločiui tarp pirmųjų krūminių dantų, burnaryklės tūris padidėja nuo 439,0 mm^3 iki 997,2 mm^3.

Išvados. Greitas viršutinio žandikaulio plėtimo gydymas padidina burnaryklės tūrį ir gerina kvėpavimo efektyvumą. Tačiau dėl įtrauktų tyrimų heterogeniškumo išvadas reikėtų interpretuoti atsargiai, o patikimesniems rezultatams gauti reikalingi tolesni tyrimai.

Raktažodžiai: Viršutinio žandikaulio plėtimas, viršutiniai kvėpavimo takai, morfologija, funkciniai parametrai, sisteminė apžvalga.

1. Introduction

Since the 1860s, there have been reports of using maxillary expansion as an orthodontic treatment option [1]. Rapid maxillary expansion (RME) is a typical orthodontic procedure used to correct transverse dental and skeletal deficiencies [2]. While using an orthodontic appliance, force is applied laterally on the posterior teeth or palatal mucosa, putting pressure on the midpalatal suture and increasing arch width [3]. Moreover, it is observed that RME is not only an effective method to correct transverse orthodontic anomalies but also its benefits to the upper airway are reported [4].

A few studies suggest that RME is a successful method of increasing nasal permeability and reducing airway resistance [5,6]. Reduced airway resistance lowers negative pressure during ventilation, and RME has demonstrated significant improvements in the treatment of pediatric sleep disordered breathing, including obstructive sleep apnea [7]. Increased palatal space may also result in improved tongue position, which may allow additional airway space in the oropharynx [8].

Reliable assessment of RME-induced modifications in the upper airways has always been difficult. Linear measurements on cephalograms cannot properly characterize the upper airways [9]. Recent improvements in cone beam computed tomography (CBCT) and supporting software have provided monitoring and measurement of the upper airway [10,11]. CBCT technology has become the primary method of assessing the airway because of its lower costs, lower radiation dosage, reduced scanning time, and overall accuracy compared to previous techniques [10,11] such as lateral and anteroposterior radiographs [12-14], acoustic rhinometric methods [15,16] and multislice computed tomography [17]. CBCT has also been applied in studies to assess the effects of RME on the nasal airway. Indeed, most RME investigations did not take into consideration nasopharyngeal and oropharyngeal airway volumes. Therefore, the objective of this systematic review was to evaluate nasopharyngeal and oropharyngeal volumetric changes and their correlation with skeletal and dental measurements that occur after RME treatment.

2. Materials and methods

2.1. Protocol

This systematic review was conducted and reported following the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

2.2. Focus question

According to the Participants Intervention Comparison Outcome Study design scheme (PICOS), the study included randomized, prospective, and retrospective controlled non-randomized trials (S) on human patients of any age, ethnicity or sex that underwent RME treatment (P). The intervention (I) was defined as the CBCT scan data and the comparison (C) was made between baseline and post-expansion data. The primary outcome (O) evaluated was volumetric changes in upper airways. The secondary outcome - dentoalveolar parameters.

The developed focus question was: what are volumetric and morphological changes in upper airways and dentoalveolar region in patients that underwent RME treatments.

The literature search was conducted using three electronic databases: PubMed, Cochrane Library, and Sciences Direct. Medical Subject Headings (MeSH) terms used were “rapid maxillary expansion’’ combined with “upper airways’’ and “cone beam computed tomography’’.

Inclusion criteria:

- Randomized, prospective, and retrospective studies published in English.
- Patients treated with RME appliances.
- CBCT images with radiological evaluation measurements before treatment.

Exclusion Criteria

- Literature reviews, case reports and series
- Panoramic or dental radiographs, dental casts used for evaluation,
- Patients with genetic syndromes (craniofacial syndromes, cleft lip, or palate), severe facial malformations or systemic diseases, previous orthodontic treatment, dento-maxillary traumas, agenesis.

2.3. Selection of studies

After the duplicate removal, the resulting publication's abstracts were assessed for their eligibility according to inclusion and exclusion criteria in the first stage of data selection. Two independent reviewers did the study selection process.

The reviewers compared their results and resolved differences through discussion, consulting the third person when consensus could not be reached. The person was an experienced senior reviewer. Full-text articles were screened and finally, reports were obtained for all the studies that were deemed eligible for inclusion in this paper.

Data extraction

Study characteristics including design, sample size, observation period and measurements were independently extracted by two authors.

Assessment of methodological quality

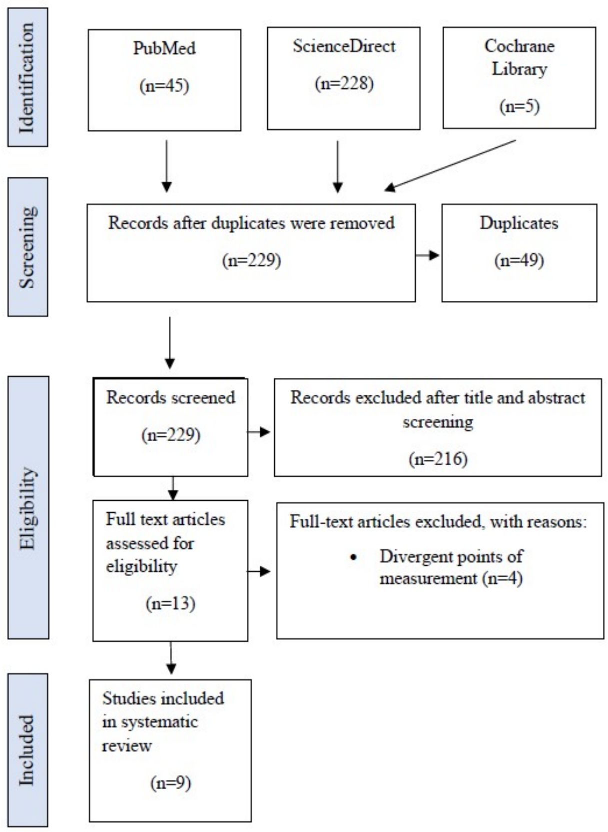
The quality of the included study protocols was assessed after study selection by investigating full-text articles. The Cochrane Collaboration suggests the use of the Newcastle-Ottawa Scale (NOS) as a tool to evaluate the quality of observational studies. This scale awards a maximum of nine points (stars) across three domains to indicate the lowest risk of bias: (1) selection of study groups (four points), (2) comparability of groups (two points), and (3) ascertainment of outcomes (three points).

3. Results

3.1. Study Selection

A total of 278 articles were identified in the electronic database. After duplicate removal and initial screening, 13 articles were chosen. Finally, 9 studies that met all selection criteria were included in this systematic review. The study selection process is illustrated in a flowchart in Fig 1.

Figure 1. *Flowchart*



3.2. Study Characteristics

The characteristics of the 9 studies included in this systematic review are given in Table 1. Concerning study design, one was a longitudinal correlation study [18], one was a single-center randomized controlled trial [19], one was a prospective longitudinal study [20], one was CBCT study [21] and the remaining 5 were cohort studies (2 prospective [22,23] and 3 retrospective [21,24,25]). The average number of patients per study was approximately 23 patients (with a minimum of 14 and a maximum of 35 patients). The total number of included patients was 206 (137 females, 69 males, an age ranging from 5 to 16 years). Samples were mixed for size, gender and age of participants [Table 1]. Inclusion criteria varied, however, the following two items were consistently reported in the majority of the studies: maxillary constriction and skeletal maturation. Moreover, posterior crossbites were found in 6 studies [18-20,23,24,26] and optional in 3 studies [21,22,25]. Prior to expansion therapy, the level of skeletal maturation of patients was assessed by using the cervical vertebral maturation index in 5 studies [18-20,23,26]. The expansion appliance used in the studies included banded RME in 8 studies [18-23,25,26], bonded RME in 1 study [24]. All of the studies [18-26] received ethical approval from their ethical committee/review board.

3.3. Nasopharynx volume

Several studies examined changes in nasopharynx volume following RME treatment [19,21,22,25]. Only two studies conducted by Aljawad et al. [25] and Cheung et al. [19] used the same measurement methodology, however, they yielded contradictory results. Aljawad et al.[25] reported a significant increase of 658.0 mm^3 in nasopharynx volume, whereas Cheung et al. [19] observed a notable decrease of 26.1 mm^3, both findings being statistically significant.

3.4. Oropharynx volume

The oropharynx results are analyzed according to the same measurement methodology used in the studies. Abdalla et al. [26] and Cheung et al. [19] measured the oropharynx within the same boundaries and found that after RME treatment, the oropharynx volume increased on average by 2955.1 mm^3. Both the studies by Dicosimo et al. [22] and Erdur et al. [24] showed an increase in oropharynx volume by 2527.2 mm^3. In contrast, El et al. [21] found a smaller enlargement in oropharynx volume by 1273.1 mm^3.

3.5. The volumes of airway compartments, oxygen saturation and apnea/hypopnea index

Caprioglio et al. [23] and Fastuca, Perinetti et al. [18] divided the airways into three parts and investigated volume changes after RME treatment. According to their studies [18,23], all airway compartments showed an enlarged volume post-treatment. The highest volume increase was observed in the upper airway, with an average rise of 2437.8 mm^3, while smaller increases were found in the middle airway (1118.3 mm^3) and in the lower airway (1746.7 mm^3).

Moreover, several studies analyzed oxygen saturation and apnea/hypopnea index(AHI) [18,20,23]. Similarly, in three studies, oxygen saturation showed a statistically significant increase of 5% on average. Additionally, improvements in the AHI index with a reduction in apneic events of 4.02 per hour, were found [18,20,23]. All three studies investigated the correlation between total airway volume and oxygen saturation and AHI, however, no correlation was observed [18,20,23].

3.6. Upper airway volume correlation with skeletal and dental measurements

Two studies by Abdalla et al. [26] and El et al. [21] reported data about upper airway and transverse skeletal and dental measurements. These studies show that with the increase in maxillary and intermolar width, oropharyngeal volume enlarges [21,26]. According to Abdalla et al. [26] study, the expansion of maxillary width by 2.9 mm and intermolar width by 4.6 mm leads to upper airway volume enlargement by 4587.2 mm^3. From this, it could be stated that an increase in maxillary width by 1 mm increases the volume by 1571.0 mm^3. Moreover, if intermolar width increases by 1mm, the upper airway volume enlarges by approx. 997.2 mm^3 [26].

Analysing El et al. [21] study, if maxillary width increases by 3.5 mm and intermolar width by 2.9 mm, the oropharynx volume enlarges by 1273.1 mm^3. From this study, it could be estimated that an increase in maxillary and intermolar width by 1 mm results in an enlargement of the oropharynx by 363.7 mm^3 and 439.0 mm^3, respectively [21].

Taking into account the results, the conclusion could be drawn that an expansion of maxillary width by 1mm leads to an enlargement of oropharyngeal volume from 363.7 to 1571.0 mm^3, as well as the intermolar width increase by 1mm raises oropharyngeal volume from 439mm^3 to 997.2 mm^3. The difference depends on the oropharynx area being assessed.

Quality Assessment

The articles included in our review were assessed using the Newcastle-Ottawa Scale and were rated as "Good" quality. Ratings for our selected studies varied within the range of 7 to 8 out of a potential 9 points on the scale.

4. Discussion

Skeletal and dental effects of RME treatment have been well studied in the literature. Some authors revealed that RME affects nasal and pharyngeal morphology as well. The impact of maxillary expansion on the nasopharyngeal airways is associated with transverse displacement of the nasal lateral walls during the expansion procedure [27]. Moreover, maxillary expansion may alter the position of the lower jaw, affecting the size and volume of the oropharyngeal airway [28]. Therefore, this systematic review focused on the RME impact on the upper airway characteristics.

The preferred diagnostic technique for evaluating the volume of the upper airways is CBCT since it provides the ability to visualize a three-dimensional object and characterizes the upper airway [29].

Although a number of studies have been done, the impact of RME on pharyngeal airway volume is still debatable. Smith et al. [30] measured the pharyngeal airway volume of RME patients with CBCT. Similar to Aljawad et al. [25] included in this review, they found a significant increase in nasopharyngeal airway volume after RME treatment. Contraversely, Cheung et al. [19] reported a significant decrease in this measurement and confirmed the results of Ribeiro et al. [31] study. Evaluating the changes of oropharynx volume all authors included in the review revealed increasement. However, only Abdalla et al. [26] and Dicosimo III [22] found the results to be statistically significant. The differences across the studies might be associated with the lack of standardized position of the head and tongue, and different reference points for the pharynx [32,33].

The results of this systematic review revealed that RME is effective in improving respiratory function. All studies in this review evaluating oxygen saturation and AHI reported statistically significant improvement in these measurements [18,20,23]. Nevertheless, these findings can be compared to limited existing evidence. For instance, Villa et al. [34] found significant improvements in AHI in patients with obstructive sleep apnea after RME, which remained stable 24 months after treatment.

This review included studies that used different types of expanders, activation protocols, and observation periods. The use of different anatomic boundaries for the assessment of the upper airway was a recurring finding in our analysis, making it difficult to compare studies in this respect. Furthermore, because the follow-up periods across the studies varied, it was difficult to make conclusions about the stability of the effects observed. Due to the high heterogeneity of the studies, all except one analyses were carried out on the results of two studies. For this reason, this systematic review only reflects the general tendency towards the effect of RME on the upper airways morphology and functional parameters. Further high-quality studies are required for more reliable results.

5. Conclusions

Despite the controversial results observed in the evaluation of nasopharyngeal volume changes, RME treatment tends to increase oropharyngeal volume and improve respiratory performance. However, the findings should be interpreted with caution due to heterogeneity of the included studies and further research is needed for more reliable conclusions.

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Table 1. *Results of individual studies*

Author, year	Study design	Sample size	Observation period	Type of appliance	Measurements
Abdalla et al., 2019 [26]	Retrospective	26	T0 - pretreatment T1 - 6 months posttreatment	RME Hyrax expander	Oropharynx volume Maxillary width Maxillary intermolar width
Dicosimo III, 2021 [22]	Retrospective	28	T0 - pretreatment T1 - 3 months posttreatment	RME Hyrax expander	Oropharynx volume Nasopharynx volume
Erdur et al., 2020 [24]	Retrospective	30	T0 – pretreatment T1 – 3 months posttreatment	RME, asymmetric rapid maxillary expansion (ARME)	Oropharynx volume
Caprioglio et al., 2013 [23]	Prospective	14	T0 – pretreatment T1 – 12 months posttreatment	Haas type expander	Upper airway volume Middle airway volume Lower airway volume Total airway volume Apnea/hypopnea index(AHI) Oxygen saturation
Aljawad et al., 2021 [25]	Retrospective	17	T0 – pretreatment T1 – 4 months posttreatment	RME Hyrax expander	Nasopharynx volume Oropharynx volume
El et al., 2014 [21]	Retrospective controlled study	35	T0 – pretreatment T1 –7 4-6 months posttreatment	RME Hyrax expander	Oropharynx volume Nasopharynx volume Maxillary width Maxillary intermolar width
Fastuca, Perineti et al., 2015 [18]	Longitudinal correlation study	15	T0 –pretreatment T1 – 12 months posttreatment	Haas-type maxillary expander	Upper airway volume Middle airway volume Lower airway volume Total airway volume Apnea/hypopnea index(AHI) Oxygen saturation
Cheung et al.,2021 [19]	Single-centre randomized controlled trial	19	T0 – pretreatment T1 – 6 months posttreatment	Hyrax, Hybrid-Hyrax, and Keles keyless RME expanders	Oropharynx volume Nasopharynx volume
Fastuca,Matteo et al., 2015 [20]	Prospective cohort study	22	T0 – pretreatment T1 - 12 months posttreatment	Haas type expander	Apnea/hypopnea index(AHI) Oxygen saturation