

## Review Article

# Oropharyngeal airway changes after rapid maxillary expansion: the state of the art

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**Abstract:** The aim of this article is to elucidate the state of the art about how rapid maxillary expansion (RME) produces changes in the oropharyngeal airways in terms of CBCT (Cone Beam Computed Tomography) data during the growth period, according to the available literature. Electronic search was done from January 2009 to April 2014 on *PubMed* and *Scopus* databases; in addition manual search was conducted as well. According to keywords, seven papers were eligible for our purpose, but definitely five papers were selected in agreement with the inclusion/exclusion criteria. The current literature suggests that the potential relationship between RME and oropharyngeal airway changes is still unclear. In fact, although the pharyngeal airway changes after the rapid palatal expansion are evident clinically, current orthodontic literature does not provide conclusive evidence about the nature of this relationship.

**Keywords:** Rapid maxillary expansion, upper airways, rapid palatal expansion, children

## Introduction

The techniques of rapid maxillary expansion were born more than a century ago (precisely in 1860) and have been shown to be a reliable and an effective method in the treatment of patients with the constriction of the palate [1, 2]. Nowadays, many new appliances have been developed, but the final aim remains the same. The RME appliances, fixed to the teeth can produce heavy forces of 15 to 50 Newton that separate the midpalatal suture, providing orthopedic movement of the maxillary bones with minimal orthodontic tooth movement [3-5]. Several authors report changes in pharyngeal airways caused by RME, studied by Cone Beam Computed Tomography or Cephalometric Analysis [6]. Also, the rapid maxillary expansion can provide changes in cervical posture [7]. Lateral and posteroanterior cephalometric radiographs have been used often in the past to compare the dimensional changes in the upper airways but precise measurements of pharyngeal airway with these methods are very difficult. First of all because anatomy is different among the patients, and later because the different structure superimpositions and image magnifications did not always allow an

accurate quantifications of the changes [8]. However the complexity of the three-dimensional airway anatomy suggested that the CBCT is the best method of study, even though this is not without drawbacks. According to these reports, recent literature suggests modifications in oropharyngeal airway and often in the tongue posture during and after RME application. Investigating the possible impact of RME in terms of changes in oropharyngeal airway is a great and actual topic that needs to be deepened, because more aspects remain unclear. At today, the gold standard for studying upper airway changes is the CBCT analysis. However, the influence of RME in the oropharyngeal airway can be analyzed with reference to objective measurements from studies using comparable CBCT data.

## Materials and methods

### Research strategy

A literature search was performed searching English-language articles. The following electronic databases were selected for search from January 2009 to April 2014: *PubMed* and *Scopus*. The database queries were performed

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**Table 1.** Electronic databases used and search strategy

Database	Search strategy Key words	
PubMed <i>http://www.ncbi.nlm.nih.gov/pubmed/</i>	<i>Rapid palatal expansion(s) OR Rapid maxillary expansion(s) OR RME OR</i>	abnormalities, or skeletal open bite; 2. Absence of complete data from the beginning of therapy to the end of the follow-up;
Scopus <i>www.scopus.com/home.url</i>	<i>Rapid maxillary expansion treatment(s) OR Rapid palatal expansion treatment(s) OR RPE OR Rapid palatal disjunction(s) OR Rapid maxillary disjunction(s) AND Pharyngeal airway changes OR Upper airway changes AND Cone Beam Computed Tomography OR CBCT</i>	3. Studies involving the use of Cephalometrics; 4. No data for the evaluation of inclusion/exclusion criteria.

independently by two reviewers (EO and AM) according to key words listed in **Table 1**. Animal studies, abstracts, letters, case reports, and reviews were excluded. Disagreement regarding inclusion was resolved by discussion. To avoid inappropriate exclusions, adjectives, nouns, plural and singular forms of all terms were used. In addition, a manual search was performed in the following journals: *European Journal of Orthodontics*, *American Journal of Orthodontics and Dentofacial Orthopedics*, *Angle Orthodontist* and *Australian Orthodontic Journal* from January 2009 to March 2014.

The search resulted in a total of 7 articles and, subsequently, a final eligibility screening was conducted to verify the agreement with the inclusion and exclusion criteria listed below.

### *Inclusion criteria*

1. Randomized controlled trials (RCTs), clinical trials (CTs) and historical, groups for clinical trials (HCTs);
2. Follow-up of at least 6 months after RME/RPE therapy;
3. Subjects during growth period (<16 years);
4. The use of TC cone beam to evaluate the oropharyngeal airway changes before and after the treatment.

### *Exclusion criteria*

1. Studies involving patients with systemic diseases, psychosocial impairment, craniofacial

A total of five articles were included according to both inclusion and exclusion criteria [3, 4, 9-11]. These are summarized in **Table 2** with notations regarding Authors, year of publication, sample size, treatments and pharyngeal airway changes results.

### **Results**

Five studies were identified for the aim of our paper. Zhao et al [9]. studied the changes in pharyngeal airways after RME in 48 patients. The treatment and the control groups consisted of 24 and 24 patients, respectively. The test subjects underwent RME treatment for bilateral or unilateral crossbite using a hyrax type expander banded on the maxillary first premolar and first molar. The midline expansion screw was activated twice a day until the desired change in the transverse dimension was achieved. The appliance was left in place for at least three months post-expansion. The control subject had regular orthodontic treatment (no RME) only. CBCT scans were taken of all patients as part of both initial orthodontic treatment records and progress records (midpoint of the total treatment time, from 8 months to 2 years; average, 15 months). The total oropharyngeal airway volume was defined as the airway volume between the 2 planes as follows: the superior plane was defined on the midsagittal image as the horizontal line through the posterior nasal spine, and the inferior plane was defined as the horizontal line through the superior point of the epiglottis. Last, the oropharyngeal airway volume was divided into retropalatal and retroglossal airway volumes by creating

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**Table 2.** Characteristics of the selected studies

Study	Sample size	Treatment design	Age	Sex	Type of treatment	Criteria of study
Zhao et al [9]	48	24 patients (test)	12.8±1.88	36 F	RPE	CBCT before and after the treatment
		24 patients (control)	12.8±1.85	12 M		
Iwasaki et al [10]	48	28 patients (test)	9.96±1.21	27 F	RPE	CBCT before and after the treatment
		20 patients (control)	9.68±1.02	21 M		
Chang et al [3]	14	14 patients (test)	12.9	9 F	RME	CBCT before and after the treatment
		0 patients (control)		5 M		
Ribeiro et al [4]	15	15 patients (test)	7.5 years	8 F	RPE	CBCT before and after the treatment
		0 patients (control)		7 M		
El et al [11]	70	35 patients (test)	14.02±1.46	30 F	RPE	CBCT before and after the treatment
		35 patients (control)	14.10±1.44	40 M		

a horizontal plane through the inferior point of the uvula. The molar-to-molar width was measured as the distance between the lingual alveolar crests at the level of the first molars for all patients (test and controls). After treatment, no significant differences in absolute and percentage changes of total oropharyngeal airway volume, retropalatal airway volume, or retroglottal airway volume between the RPE group and the controls were found.

Iwasaki et al [10] studied the possible oropharyngeal airway change after RME in 48 patients. CBCT data were taken before and after RME treatment (RME group) or at corresponding times but without RME treatment (control group). The RME group consisted of serial CBCT images of 28 subjects (13 boys, 15 girls) with mean ages before and after RME of 9.96±1.21 and 11.23±1.12 years, respectively. The subjects in the test group were also divided in subjects with or without nasal obstruction. They required approximately 5 mm of maxillary expansion as part of their orthodontic treatment. No passive retention appliance was used before full orthodontic treatment. The mean treatment time with the RME appliance was 5.5±1.0 months. The control group consisted of serial CBCT images of 20 subjects (8 boys, 12 girls) with no history of RME appliance treatment. Control CBCT images were taken at age 9.68±1.02 years (corresponding to before RME) and at age 11.13±1.31 years (corresponding to after RME). The control subjects were approximately matched by sex, age, and dentition with the RME subjects. The following pharyngeal airway volumes were measured as: (1) total pharyngeal airway volume, the airway between the palatal plane and the epiglottis

plane; (2) retropalatal airway volume, the airway between the palatal plane and the soft palatal plane; and (3) oropharyngeal airway volume, the airway between the soft palatal plane and the epiglottis plane. The authors comprehensively examined the effect of RME on nasal airway ventilation condition, tongue posture, and pharyngeal airway volume. Children with nasal airway obstruction have a low tongue posture regardless of RME treatment. Improvement of the nasal airway ventilation condition by RME is associated with improved low tongue posture. RME enlarges the pharyngeal airway both with and without improvement in nasal obstruction.

Chang et al [3] analyzed the use of CBCT to assess the dimensional changes of the upper airways after the RME in 14 children with the main age of 12.9 years. All patients were treated with a hyrax type of maxillary expander banded to the maxillary first premolars and first molars. The activation protocol consisted of 1 activation (90° turn) of the jackscrew per day for 28 consecutive days or until resolution of the posterior crossbite. Clinical observation of 2 to 3 mm of overexpansion marked the termination of expansion; the beginning of the retention phase consisted of tying off the jackscrew with a ligature wire and placing composite material over it. No additional orthodontic treatment was initiated in both jaws until after the retention phase started. The initial CBCT scan was taken 0 to 14 days before cementation of the maxillary expander, and the progress CBCT scan was taken 3 to 4 months after completion of active maxillary expansion to allow new bone to fill in the space at the midpalatal suture and the skeletal expansion to become stable (Proffit

W. Contemporary orthodontics. 4th ed. St Louis: Mosby; 2007. p. 286.). The upper airway was defined as the airway volume between the 2 planes as follows: the superior plane, arbitrarily called the "P plane", was defined on the midsagittal image as the horizontal line connecting the posterior nasal spine to basion and the inferior plane, arbitrarily called the "EP plane", was defined as the horizontal line passing through the most superior point of the epiglottis. The upper airway was divided into 2 segments to further evaluate the specific effects of RME. The upper segment or retroalatal airway was limited superiorly by the P plane and inferiorly by a horizontal plane crossing the most posteroinferior point of the soft palate, arbitrarily called the "SP plane". To increase the accuracy of the airway measurements, once the posterior nasal spine and basion points were selected in the midsagittal view, the P plane was reoriented so that it became parallel to the floor, and subsequent planes (SP and EP) were traced parallel to the P plane. The inferior segment or the retroglossal airway was limited superiorly by the SP plane and inferiorly by the EP plane [9, 12]. The results of this study confirm the findings of others studies that RME produces a significant expansion of the maxilla. Additionally, they found that only the cross-sectional area of the upper airway at the posterior nasal spine to basion level significantly gains a moderate increase after RME.

Ribeiro et al [4] evaluated 15 patients with maxillary width deficiency treated with RME. Patients were subjected to CBCT at the beginning of RME and after the retention period. The sample was composed of 15 pairs of tomographic images acquired by three dimensional volumetric CBCT corresponding to 15 mixed dentition individuals (8 females and 7 males). These patients had a transverse maxillary deficiency and a unilateral posterior crossbite, and they had an average age of 7.5 years at the beginning of treatment. All patients were treated with rapid maxillary expansion using a fixed appliance with occlusal acrylic coating. For evaluation of the oropharynx, the upper limit of the epiglottis was identified in the coronal plane, cut as this is in its greatest length, and its uppermost portion was landmarked. With the image in sagittal, this region was delimited by joining a point located 15 mm anterior and posterior, respectively, from the point of the

uvula. Finally the study suggests that RME produces a significant transversal increase in the lower third of the nasal cavity 4 months after the procedure. There was no significant change in volume, sagittal median area, or axial minimal area in the nasopharynx as a result of the RME. A significant change in the oropharynx was noted after the RME; however, this change may reflect inconsistencies in the examination acquisition because tongue posture, head inclination, and breathing and swallowing movements were not standardized between patients.

El et al [11] evaluated the CBCT scans, obtained from an existing patients database, of a group of 35 patients (15 females and 20 males) who underwent RME and of a control group of 35 patients (15 females and 20 males) who underwent comprehensive orthodontic treatment. The RME group consisted of patients with maxillary constriction treated with Hyrax maxillary expanders, and the control group was a sample matched for age, sex, and treatment duration who underwent regular orthodontic treatment without expanders. Expansion protocol consisted of twice per day screw activation until a slight amount of overcorrection was achieved. Screws were then stabilized, and the expander was passively left in place for 4-6 months. The superior limit of the oropharyngeal airway is the palatal plane (ANS-PNS), extending to the posterior wall of the pharynx, and the inferior limit is a line parallel to the palatal plane, touching the most anteroinferior point of the second cervical vertebrae. The present study confirms the presence of no effect on pharyngeal airway when using RME.

### Discussion

This manuscript focused on changes produced by RME on the oropharyngeal airway. The benefits of the rapid palatal expansion on the dimensions of the jaws, pharyngeal structures and facial structures have been studied by orthodontists and otorhinolaryngologists [4, 13, 14]. The rapid palatal expansion is a therapeutic technique to great effect, whose expression at the level of the structures of bones and upper airway has not yet to be fully established. Because of the great complexity of human anatomy and function, several measurement methods have different objectives and can complete each other to assess the real chang-

es. Before the use of the CBCT data, that allow a three-dimensional study of skull, the authors in the remote studies used lateral and postero-anterior cephalometric radiographs. Although cephalometric data in the studies were taken according to a standardized technique, the different structure superimpositions and image magnifications did not always allow accurate quantifications of the changes. Moreover, the accuracy and quality of images obtained by computed tomography have led the authors to choose this method. However, some errors may result from the incorrect positions of the patients for the CBCT technique. These factors could be influenced by the variable position of the head. Also, the use of different software obviously different in each studies, can influence the results (for example Dolphin software or Vwork software [4, 9]). Evaluation of the oropharyngeal airway is more important in dentistry and especially in orthodontics, the potential impact of high resistance airways determines an abnormal growth of the nasomaxillary complex, resulting in an increased of vertical facial dimension and in the originbirth of obstructive sleep apnea [3, 5, 15, 16]. Maxillary constriction in particular has been postulated to play a role in the pathophysiology of obstructive sleep apnea because the low tongue posture could contribute to narrowing the pharyngeal airway [17]. Ricketts already in 1968 had defined the implications related physiologic maxillary hypoplasia syndrome by nasal obstruction: the microrrhinosis, adeno-tonsillar hypertrophy, soft palate directed vertically, the tongue posture and lower front. The rapid maxillary expansion involves both the increase of the total volume of the nasal cavities, with consequent increase the air flow, which a better posture of the tongue and soft palate. All this determines the partial or total restoration of the proper functions of the nasal breathing [18-20].

Iwasaki et al [10] in their study established that RME enlarges the pharyngeal airway both with and without improvement in nasal obstruction. They analyzed also the tongue posture after the RPE, and more specifically the relative lingual position of the palate was used to evaluate tongue posture. Factors affecting tongue posture include mouth breathing, nasal airway ventilation, arch width and palatine tonsil hypertrophy. Chronic upper airway obstruction has been

associated with a low tongue posture [21-23]. The habitual mouth breather, who breathes through the mouth even though there is no obstruction in the airway, was considered to have a low tongue posture [24, 25]. In the study of Iwasaki et al., subjects with nasal airway obstruction showed a low tongue posture both before and after RME, indicating an association between nasal obstruction and low tongue posture regardless of RME treatment [10]. The others authors cited in this manuscript did not show significant differences in the changes in the upper airways after the palatal expansion. But, a big limitation of these studies, is the different type of protocols for the rapid palatal expansion. In fact, the protocols are different and the authors are not sure if the patients and their parents had complied strictly with the activation regimen. In some studies, we can also find a particular slow palatal expansion. Finally the greatest disadvantage in the use of this technique is the high number of radiation to which is subjected the orthodontic patient. These techniques should be reviewed by an ethical point of view, the authors remain skeptical and hope for the future implementation of a new technique for the analysis of anatomical changes that do not lead to an x-ray risk, especially for orthodontic and pediatric patients. The use of CBCT is limited also by high cost and restricted accessibility.

### Conclusion

From the analysis of the recent scientific literature, it has been noted that RME causes not only dentoalveolar changes, but also oropharyngeal airway changes. In conclusion, this manuscript suggests that the potential relationship between RME and oropharyngeal airway is still unclear. Although it is evident a change in the oropharyngeal airway after the rapid palatal expansion, it cannot be quantified in an objective way since the few studies reported in the literature did not use the same evaluation method. CBCT data, and different measurement techniques do not allow to quantify properly the actual change. There is a need for further well controlled long-term clinical trials using most precise methods to measure upper airway anatomy and its function and to look at the data for a longer observation period. There is also a need of Long-term stability results in the Rapid palatal expansion.

## Disclosure of conflict of interest

None.

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