Effects of non-surgical rapid maxillary expansion on nasal structures and breathing: A systematic review

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Summary

Objective > This systematic review aims to determine the effects of non-surgical rapid maxillary expansion (RME) on breathing and upper airway structures.

Materials and methods > An electronic search of the scientific literature from January 2005 to June 2016 was done using Web of Science, Dentistry & Oral Sciences Source and PubMed databases. A combination of search terms “rapid maxillary expansion”, “nasal”, “airway” and “breathing” were used. Studies that involved surgical or combined RME-surgical treatments and patients with craniofacial anomalies were excluded.

Results > The initial screening yielded a total of 183 articles. After evaluation of the titles, abstracts and accessing the full text, a total of 20 articles fulfilled both inclusion/exclusion criteria and possessed adequate evidence to be incorporated into this review.

Conclusions > Non-surgical RME was found to improve breathing, increase nasal cavity geometry and decrease nasal airway resistance in children and adolescents.

Résumé

Effets de la disjonction non chirurgicale sur les structures nasales et la ventilation: étude systématique

Objectif > Cette revue systématique vise à déterminer les effets de la disjonction (rapid maxillary expansion) non chirurgicale sur les structures respiratoires et les voies aériennes supérieures.

Matériels et méthodes > Une recherche électronique dans la littérature scientifique de janvier 2005 à juin 2016 a été effectuée à l’aide des bases de données Web of Science, Dentistry & Oral Sciences Source et PubMed. Une combinaison des termes de recherche « expansion maxillaire..."
Introduction

Transverse maxillary deficiency (TMD) is a common craniofacial skeletal problem. It is often associated with antero-posterior and/or vertical skeletal incoherences and presents in both syndromic and non-syndromic patients [1]. The aetiology of TMD is complex and multi-factorial, encompassing congenital, genetic, developmental, traumatic and/or iatrogenic causes [2–5]. Contributing factors include a variety of craniofacial syndromes, thumb/finger-sucking habits and mouth breathing during facial growth as well as trauma or surgical complications during cleft palate repair. The reported incidence of TMD ranges from 8.5 to 22% in children and adolescents [6]. The wide range can be attributed to a lack of universally accepted classification, diagnostic criteria and methods for scoring inadequacies of dental and skeletal components [6–8]. Incidence does not appear to be influenced by gender or ethnicity [9] and prevalence in the adult population is not known. The most frequently reported clinical manifestations of TMD are uni- or bilateral posterior crossbites, palatal inclination of teeth, crowding of teeth, high palatal arches, narrow/tapering arch forms and problems related to nasal respiration [9]. Unlike vertical or sagittal discrepancies, TMD is hard to diagnose extra-orally. The extra-oral expressions are often discrete and confined to contracted alar bases, para-nasal excavations and deep nasolabial grooves. They are commonly masked by concomitant vertical and sagittal anomalies. Correction of TMD usually requires expansion of the palate by a combination of orthopaedic and orthodontic tooth movements. Three expansion modalities are employed nowadays. They are rapid maxillary expansion (RME), slow maxillary expansion (SME) and surgically assisted rapid maxillary expansion (SARME). Disagreements exist pertaining to their indications due to their comparative advantages and disadvantages [10]. RME is probably the most popular modality among the three. Haas first proposed the use of fixed palatal expanders to rapidly correct TMD in children and adolescents in the 1960’s [3,11]. Fixed palatal expanders were found to unstable and ineffective in mature patients [12]. Complications of non-surgical RME in adults have been described and includes expansion relapse, molar tipping, opening rotation of the mandible, gingival recession, bone loss, root resorption, pain and swelling [13,14]. The midpalatal suture begins to fuse by the late teens and becomes relatively rigid in adults [15,16]. Surgical interventions are therefore indicated in mature, non-growing patients. Many studies have reported the success of surgically assisted rapid maxillary expansion (SARME) for separating the midpalatal suture and widening of the maxillary arch [13,17–19].

A systematic review on the effect of SARME on upper airway volume was recently published [20]. The authors concluded that SARME produced a substantial short-term increase in nasal volumes but had no effect on oropharyngeal volumes in non-growing patients. Effect of volume changes on respiratory function could not be determined. The last systematic review on RME on airway dimensions and breathing was conducted about 5 years ago [21]. The authors concluded that RME in growing children improved nasal breathing and results are stable up to 11 months after therapy. In view of the advances in RME appliances and protocols as well as supplementary clinical trials over the past few years, an update on this subject matter is required. This systematic review aims to re-appraise the available literature on the effects of non-surgical RME on breathing and upper airway structures. It was hypothesized that non-surgical RME decreases nasal airway resistance, increases nasal cavity dimensions and nasal volume in children and adolescents.

Materials and methods

An electronic search of the scientific literature from January 2005 to June 2016 was done using Web of Science, Dentistry & Oral Sciences Source and PubMed databases. A combination of search terms “rapid maxillary expansion”, “nasal”, “airway” and “breathing” were used. Inclusion criteria for the review included: clinical (randomized controlled, retrospective and prospective cohort) studies that used one or more of the following investigations: rhinomanometry (RMN), cone-beam computed tomography (CBCT), conventional tomography and radiography for measuring of RME effects. Reviews, clinical case reports, case series and opinion papers were excluded as were studies...
involving surgical or combined RME-surgical treatment pre-, during and/or post-expansion, syndromic subjects with craniofacial anomalies. Titles and abstracts of potentially relevant articles were screened and evaluated according to the inclusion and exclusion criteria. The identified publications were then secured and appraised. Electronic search was complemented by manual-search in the reference list of the selected publications where applicable.

**Results**

A total 183 titles were ascertained for the period of January 2005 to June 2016 (figure 1). Duplicate records appearing in more than one database were discarded. From the titles, only 52 abstracts were relevant to this review. Of these abstracts, only 20 publications fulfilled both inclusion/exclusion criteria and possessed satisfactory evidence to be appraised. For discussion purposes, the articles were grouped into those concerning breathing and those related to airway structures.

**Discussion**

**Effects of non-surgical RME on airway structures (table 1)**

Changes at the nasal floor adjacent to the midpalatal suture following non-surgical RME had been reported [11,22]. The transverse skeletal maxillary thickness and nasal cavity widths were found to be significantly increased post-RME [23,24] leading to decreased airway resistance [25-27]. A few authors investigated the association between RME and nasal airway resistance (NAR) [26-28]. Collectively these studies indicated that RME reforms the nasal valves of patients and decreases NAR during breathing. There were, however, subjective variations in treatment planning and expansion appliances used in these studies. In addition, the stability of airway structures with RME over time and its effect on NAR was unclear [26,29]. Studies assessing the effects of RME on NAR and dimensions are summarized in table 1. From these studies, it is evident that non-surgical RME increases nasal geometry and the increase in transversal nasal measurements ranged from 2 to 4 mm. Enoki et al. [30] and Compadretti et al. [31] estimated the changes in the cross-sectional area of the nasal cavities in children with mixed dentition. Enoki et al. [30] found no difference in the cross-sectional area at the level of the valve and inferior nasal turbinates despite a statistical reduction in NAR after expansion. Compadretti et al. [31] reported a decrease in NAR. They, however, related a significant increase in cross-sectional area, total nasal volume, nasal cavity width and inter-zygomatic distance after RME treatment using rhinomanometry, acoustic rhinometry and postero-anteriordigraphs. In 2007, Doruk et al. [32] assessed the effects of RME on nasal volume with computed tomography (CT) and acoustic rhinometry (AR) at the start of and 6 months after expansion. Both methods showed significantly increased nasal volume and correlation analysis showed no difference in volume using either of the two methods. In the same year, Palaisa et al. [33] examined the nasal cavity area and volume using CT in 19 cases of RME. Significant increases in the anterior nasal cavity area from pre-to post-
expansion (11.7%), from post-expansion to post-retention (22.2%) and from pre-expansion to post-retention (35.7%) were found. In addition, they discovered similar increases of 10% and 15% in middle and posterior nasal cavity volumes during post-expansion and post-retention, respectively. These alterations were mainly stable at different retention periods.

Furthermore, Görgülü et al. [34] and Haralambidis et al. [35] evaluated the results of RME on nasal cavity volume by utilizing modelling applications and 3-dimensional simulation. Görgülü et al. [34] substantiated that expansion within the anterior element of the maxillary bone was higher than the posterior component, and expansion was greatest at the coronal level and...
lower towards the cranial level for all the parameters measured. Haralambidis et al. [35] also observed a significant increase (11.3%) in the nasal volume. Oliveira et al. [36] found that RME involved the separation of the maxillary bones in a pyramidal shape, where the highest enlargement is at the level of the incisors, slightly below the nasal valves. Additionally, palatal disjunction may cause a total volume increase within the nasal cavity as the lateral partitions are moved far apart. In contrast, Itikawa et al. [37] and Matsumoto et al. [38] assessed the effects of RME on facial morphology and nasal cavity dimensions of young children and observed a significant increase in nasal and maxillary transversal bony width. No difference in nasal volume was, however, detected as mucosal changes were slighter greater than bony ones when RME was employed. More studies are thus warranted to confirm the outcomes of non-surgical RME on dimensional changes of upper airway structures and breathing with special emphasis on nasal mucosal changes in order to determine the long-term stability of RME. Furthermore, Langer et al. [39] concluded that RME did not influence nasal resistance or nasopharyngeal area in their long-term evaluation. They explained that the improvements in nasal airway could have occurred due to craniofacial growth, rather than RME action itself. This study was limited as only rhinomanometry was used to assess differences in the nasopharyngeal area and NAR after RME.

Smith et al. [40] assessed the airway volume, soft-palate area, and soft-tissue thickness changes before and after RME in adolescents using 3-dimensional computed tomography. They observed sizeable increases in nasal cavity volume, nasopharynx quantity, anterior and posterior facial heights, and palatal and mandibular planes. Cordasco et al. [41] evaluated the effects of RME on skeletal nasal cavity size in growing subjects and found that RME produced significant skeletal transverse increases in the nasal and palatal regions. The increases were bigger within the lower part of the nasal cavities. In addition, RME is capable of increasing the skeletal nasal cavity volume by about 0.08 to 0.10% of the pre-expansion volume. The increasing dimension is equally allotted between the anterior and the posterior parts of

<table>
<thead>
<tr>
<th>Study/year</th>
<th>Number of cases</th>
<th>Parameters</th>
<th>Effects of RME</th>
<th>Are results stable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monini et al. [46]/2009</td>
<td>65 cases younger than 12 years</td>
<td>Assessment of nasal flow in young children</td>
<td>There was an improvement of nasal respiration in children via a widening effect on the nasopharyngeal cavity</td>
<td>NM</td>
</tr>
<tr>
<td>Aloufi et al. [50]/2012</td>
<td>30 cases with a mean age of 14.2 years</td>
<td>Upper and lower pharyngeal airway spaces</td>
<td>Positive effect on the upper pharyngeal airway. RME did not significantly improve the mode of breathing</td>
<td>NM</td>
</tr>
<tr>
<td>Iwasaki et al. [47]/2012</td>
<td>23 cases with mean age 10.2 years</td>
<td>Use computational fluid dynamics to estimate the effect of rapid maxillary expansion on nasal ventilation</td>
<td>Improvement of nasal airway ventilation by rapid maxillary expansion was detected by computational fluid dynamics</td>
<td>NM</td>
</tr>
<tr>
<td>Iwasaki et al. [48]/2014</td>
<td>25 cases with a mean age 9.7 years</td>
<td>Evaluate changes in ventilation conditions using computational fluid dynamics</td>
<td>The nasal airway ventilation conditions was improved and constriction of the pharyngeal airway less likely after RME</td>
<td>NM</td>
</tr>
<tr>
<td>Caprioglio et al. [49]/2014</td>
<td>14 cases with a mean age 7.1 ± 0.6 years</td>
<td>Airway volume</td>
<td>Increases of total airway volume</td>
<td>NM</td>
</tr>
<tr>
<td>Fastuca et al. [51]/2015</td>
<td>15 cases with a mean age 7.5 ± 0.3 years</td>
<td>Airway volume and oxygen saturation</td>
<td>The upper, middle, and lower airway volumes were significantly increased and oxygen saturation was increased</td>
<td>NM</td>
</tr>
<tr>
<td>Izuka et al. [53]/2015</td>
<td>25 cases with a mean age 10.5 years</td>
<td>Upper airway dimensions</td>
<td>Significant increase in airway volume of the nasopharynx and nasal cavities as well in anterior and posterior widths of the nasal floor</td>
<td>NM</td>
</tr>
</tbody>
</table>

RME: rapid maxillary expansion; NM: not mentioned.
improving constriction

Effects of non-surgical RME on breathing (table II)

Effect volume, oxygen saturation and apnoea/hypopnea index were, however, statistically significant. In contrast, Aloufi et al. [50] assessed mode of breathing and pharyngeal airway after RME. They reported that maxillary expansion during orthodontic treatment could have a positive effect on the upper pharyngeal airway, but had no significant effect on the lower airway and mode of breathing. The authors, however, utilized lateral cephalometric radiography and not 3D imaging. More recently, Fastuca et al. [51] evaluated the alterations in airway volumes and respiratory performance in patients treated with RME using CBCT scans. They found that RME treatment caused significant increases in upper, middle, and lower airway compartment volumes, and also confirmed that the lower baseline airway volumes of the middle and lower compartments were associated with greater increases in SpO₂. According to the results of this study, the bony expansion seemed to induce a good response in the respiratory mucosal tissue, even though this remained questionable [52] in the anterior and posterior widths of the nasal floor. It was also found to significantly improve the quality of life of mouth-breathing patients [53]. Although past studies suggest a positive effect of RME on breathing in children/adolescents, more studies employing computational fluid dynamics and longer retention periods are warranted before a definitive conclusion can be derived.

Conclusion

Based on the reviewed literature, RME appears to improve breathing, increase nasal cavity geometry and decrease nasal airway resistance in children and adolescents. As the sample sizes of most previous studies were small, future studies should incorporate more subjects and longer retention/observation periods. In addition to rhinometry, the use of computational fluid dynamics should be considered to give more accurate evaluations of the effect of RME.

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A Review of the Literature

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