Original Article

Rapid maxillary expansion versus middle ear tube placement: *Comparison of hearing improvements in children with resistance otitis media with effusion*

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ABSTRACT

Objective: To test the null hypothesis that there are significant differences in hearing improvements of children with resistance otitis media with effusion (OME) who undergo a rapid maxillary expansion (RME) procedure or ventilation tube placement.

Methods: Forty-two children between 4.5 and 15 years old were divided into three groups: RME, ventilation tube, and control groups. The RME group consisted of 15 children with maxillary constriction and resistance OME that indicated ventilation tube placement. The ventilation tube group consisted of 16 children for whom ventilation tube placement was indicated but no maxillary constriction. The control group consisted of 11 children with no orthodontic and/or rhinologic problems. Hearing thresholds were evaluated with three audiometric records: (1) before RME/ventilation tube placement (T0); (2) after RME/ventilation tube placement (T1), and (3) after an observation period of 10 months (T2). The control group was matched to these periods, except T1.

Results: Hearing thresholds decreased significantly in both the RME and ventilation tube groups ($P < .001$). Hearing thresholds decreased approximately 15 and 17 decibels in the RME and ventilation tube groups, respectively, but differences in improvements were insignificant between the two study groups ($P > .05$). Slight changes were observed in the control groups.

Conclusion: The null hypothesis was rejected. RME showed similar effects as ventilation tube placement for release of otitis media and improvement of hearing thresholds levels. RME should be preferred as a first treatment option for children with maxillary constriction and resistance OME. (*Angle Orthod.* 2016;86:761–767.)

KEY WORDS: Rapid maxillary expansion; Middle ear tube; Otitis media with effusion; Hearing loss

INTRODUCTION

Otitis media with effusion (OME) is characterized by an accumulation of thick or sticky (mucoid or serous) fluid behind the eardrum in the middle ear space with no signs and symptoms of acute inflammation and infection and no perforation of the tympanic membrane.[1] The etiology of OME in children may be multifactorial; the exact etiology is uncertain, but for children with recurrent episodes of acute otitis media or OME, anatomic (structurally immature Eustachian tube) or a physiologic abnormality of the Eustachian tube appear to be some of the most important factors.[1] Children with Eustachian tube dysfunction leading to hearing loss and resistance OME are candidates for ventilation tube insertion (grommets).

Due to the high rate of spontaneous resolution of the disease and the costs and complications associated with surgical treatment, "watchful waiting" has been recommended as the first line of treatment.[2] This spontaneous resolution often occurs in a median duration of 3 months. However about 50% of those recovering will have a further episode of OME.[3] Thereafter, a medical treatment including antihista-

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mines, decongestants, steroids, or antibiotics may be prescribed for recovery of OME.[4] The current literature suggests that antihistamines and decongestants are ineffective for OME. Antimicrobials and corticosteroids do not have long-term efficacy and are not recommended for routine management.[4]

Insertion of a ventilation tube (grommets) into the eardrum under general anesthesia is a common pediatric surgical procedure that can produce a mean 62% decrease in effusion prevalence.[4] This procedure is associated with considerable health care costs.[4]

The rationale for inserting a ventilation tube is to improve ventilation, pressure regulation, and re-pneumatization in the middle ear by aiming for a recovery of Eustachian tube dysfunction in the long-term.[1] Some authors[5] have noted that abnormal or impaired Eustachian tube functions are seen more frequently in children with high palatal arches (constricted maxillary arches) as well as malformations of the palate and nasopharynx that might predispose the patient to otitis media. Another association has been made between maxillary constriction and middle ear effusion, otitis media, and conductive hearing loss (CHL).[6]

Rapid maxillary expansion (RME) widens the maxillary arch in the transversal direction mainly by separating the two maxillary halves.[6] RME can improve hearing impairments.[7] Children with maxillary constriction and concomitant CHL,[7] recurrent otitis media and adenoid hypertrophy,[8] recurrent serous otitis media,[9] and middle ear dysfunction have undergone RME in the past two decades.

The rationale for use of RME appliance is approximately same as for insertion of ventilation tube placement regarding recovery of Eustachian tube dysfunctions: stretched tubal dilator muscles open the pharyngeal orifice of the Eustachian tube after skeletal maxillary expansion,[7] and this produces improvement in Eustachian tube functions.

No study has evaluated the effects of RME on improvements in hearing loss of children in whom ventilation tube placement is indicated because of resistance OME. In addition, no study has been conducted to compare ventilation tube placement with RME.

Thus, this study aimed to assess and compare effects of RME and ventilation tube placement on hearing thresholds in children with resistance OME in whom ventilation tube placement was indicated.

MATERIALS AND METHODS

This prospective study was carried out on children between 4.5 and 15 years old. Informed consent was obtained from the legal parents of each subject before the procedure. This study was approved by the local ethics committee (approval number 2009/016). The Scientific and Technological Research Council of Turkey financially supported this study through the grant number SBAG 109S177.

Subjects were divided into three groups for this study. The RME group consisted of 15 children (8 girls and 7 boys) between 6 and 15 years old (mean age = 10.07 ± 2.72 years). To be included in the RME group, patients had to meet the following criteria: (1) maxillary constriction, (2) deep palatal vault, (3) bilateral crossbite, (4) CHL, (5) resistance OME lasting at least 3 months, and (6) indication for ventilation tube placement.

The ventilation tube group consisted of 16 children (9 girls and 7 boys) between 4.5 and 15 years (mean age = 9.14 ± 3.04 years). To be included in the ventilation tube group, patients had to meet the following criteria: (1) CHL, (2) resistance OME lasting at least 3 months, and (3) indication for ventilation tube placement. Patients who had maxillary constriction, a deep palatal vault, and bilateral crossbite were excluded from the ventilation tube group. All subjects in this group underwent ventilation tube placement under general anesthesia.

In the RME and ventilation tube groups, patients were excluded as study subjects if they had previous adenectomy operation history, recurrent upper respiratory tract infections, allergy, chronic rhinitis, cleft lip and palate, congenital or developmental deformity, or a systemic disorder.

The control group consisted of 11 children (9 girls and 2 boys) between 5 and 13 years old (mean age = 8.34 ± 2.46 years). All subjects in this group had no orthodontic and rhinologic problems, congenital or developmental deformities, or systemic disorders.

RME Procedure

RME was carried out using an acrylic bonded appliance (Figure 1) in 10 patients and a conventional Hyrax appliance (Figure 2) in 5 patients depending on the patient's dentition stage. A rigid acrylic bonded expander was used in subjects with a mixed dentition stage. A conventional Hyrax expander was used in subjects who had fully erupted upper first premolars and molars. The design of the acrylic bonded appliance used in the present study has been described by Memikoglu and Işeri.[10]

The subjects and/or their parents were told to activate the screw of the maxillary expansion appliances two times a day: one quarter turn in the morning (0.2 mm) and one in the evening (0.2 mm). The widening procedure was continued in same manner

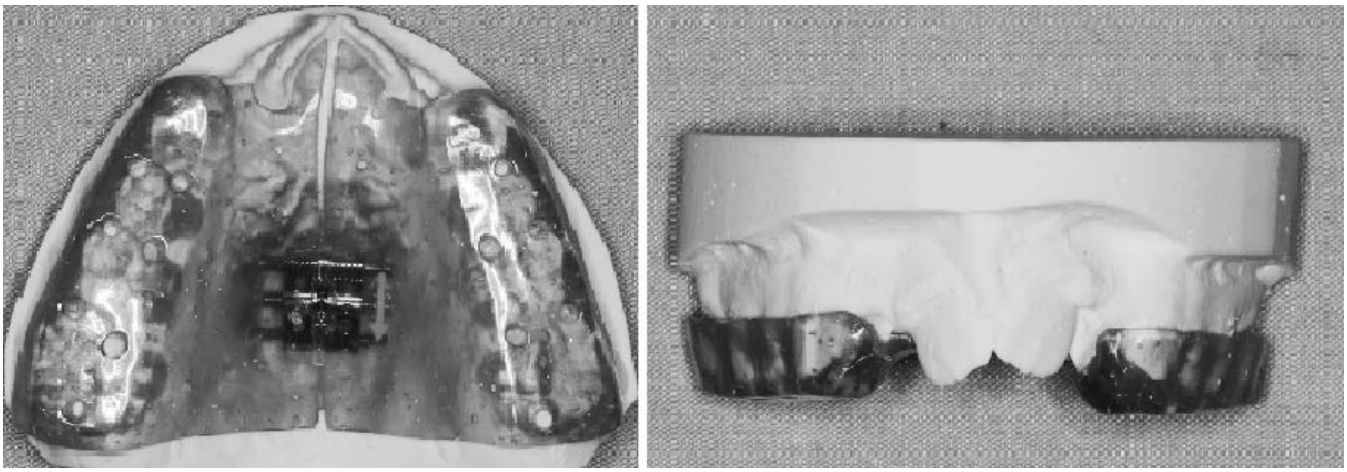

Figure 1. Acrylic bonded rapid maxillary expansion appliance.

until the crossbites were eliminated and 2–3 mm overexpansion was achieved.

RME appliances were used as a retainer for 4 months. The rigid acrylic expansion appliances were debonded, and the same appliance was used as a removable retention plate during the retention period. Conventional Hyrax expander was used as a retainer without debanding. After this retention phase, patients stopped wearing all appliances and conventional orthodontic fixed appliance treatment was applied to all subjects in the RME group.

Ventilation Tube Placement

Tubes were inserted in a standard manner under general anesthesia. Intubations were used in the case of concomitant adenoidectomy.

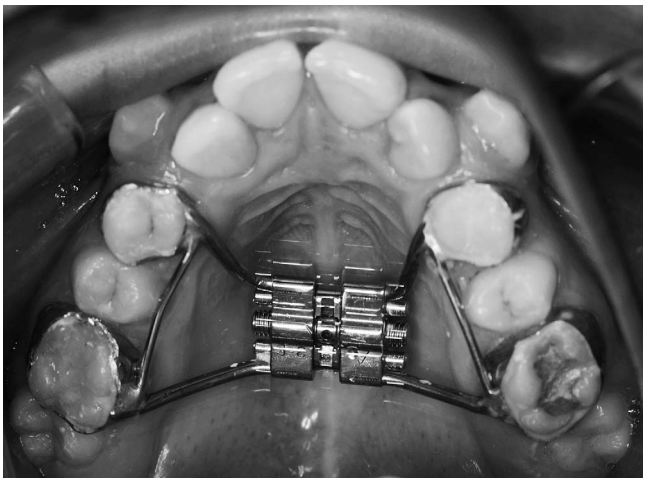

Figure 2. Conventional Hyrax rapid maxillary expansion appliance.

Pure-tone Audiometry

For the assessment of hearing thresholds, pure-tone audiogram was used. Audiometric records were obtained from all groups to assess pure-tone thresholds. Audiograms were taken under standard conditions in a room isolated from outside sounds. The hearing thresholds at the speech frequencies of 250, 500, 1000, and 2000 Hz were obtained separately for each ear. The mean pure-tone thresholds for both ears at the different frequencies, called pure-tone hearing thresholds, were calculated for each subjects and used for statistical analysis. The thresholds at speech frequencies of 4000 and 8000 Hz were excluded from this study because high frequencies are affected by middle-ear mass or inner-ear nerve damage.

Three records were obtained from each subject in the RME and ventilation tube groups: (1) before RME/ventilation tube placement (T0), (2) after RME/ventilation tube placement (T1), and (3) after an observation period of 10 months (T2). The control group was matched to these periods, except T1 (Figure 3).

Statistical Analysis

All statistical analyses were carried out using SPSS version 17.0 software (IBM Corporation, Chicago, IL, USA). The Shapiro-Wilk test was used for testing normal distribution of hearing thresholds at T0. The

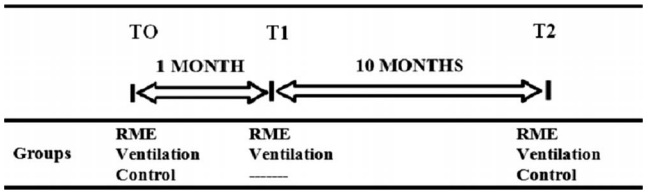

Figure 3. Diagram showing the timing of the audiograms taken in each group.

Table 1. Descriptive Values of the Age of Each Group and Their Intergroup Comparisons[a]

Group	Number	Mean	Standard Deviation	Minimum	Maximum	ANOVA
Control	11	8.34	2.46	5.42	12.67	NS
Rapid maxillary expansion	15	10.07	2.72	6.17	14.92	
Ventilation tube	16	9.14	3.04	4.50	14.33	

[a] NS indicates not significant; ANOVA, analysis of variance.

mean age of each group was calculated, and intergroup comparisons were carried out by analysis of variance (ANOVA). The audiometric data were analyzed by repeated-measure ANOVA to reveal significant changes in hearing levels (thresholds) at different recording times within groups. Repeated-measure ANOVA was also performed to reveal significance of the total changes between groups. When a significant value in repeated-measure ANOVA analysis was found, a post hoc test with a Bonferroni correction was used to determine the significance of mean differences within and between groups.

RESULTS

The Shapiro-Wilk test showed normal distribution of hearing thresholds at T0. Descriptive values of the age of each groups and their intergroup comparisons with ANOVA are shown in Table 1. No statistically significant differences were observed between groups regarding mean age (Table 1). Means and standard deviations of hearing thresholds (decibel) at different recording times of each groups showed in Table 2.

Table 3 shows results of the repeated-measure ANOVA test explaining the significances in variance analyses in each group. In the control group, hearing threshold decreased significantly (approximately 3 decibels) during the observation periods. In the RME group, hearing threshold decreased significantly (approximately 15 decibels) after maxillary expansion and remained relatively stable during the observation period. In the ventilation tube group, hearing threshold decreased significantly after ventilation tube placement (approximately 7 decibels) and during the observation period (approximately 10 decibels), producing a total improvement approximating 17 decibels (Figure 4).

Table 4 shows results of repeated-measure ANOVA test explaining the significance of total changes in hearing levels (thresholds) between the groups. As shown in Table 4, total improvements in hearing levels (T2-T0) were significantly greater in both study groups (RME and ventilation tube) than in the control group, whereas these improvements were insignificant between the RME and ventilation tube groups.

DISCUSSION

Incidence and prevalence of OME are common among children. About 2.2 million cases of OME occur annually in the United States.[11]

It has been well documented that ventilation tube placement results in a considerable decrease in effusion prevalence[4] and significant improvement in hearing impairment and Eustachian tube dysfunction.[4] However, the question as to whether the skeletal separation of hard and soft tissues of nasomaxillary and palatal tissues produced by RME has the same favorable effects on Eustachian tube dysfunction and hearing loss as that produced by ventilation tube insertion remains unanswered.

It would have been preferable to have a control group with maxillary constriction and OME without treatment and a group with just OME without maxillary

Table 2. Means and Standard Deviations (SDs) of Mean Hearing Thresholds (Decibels) at Different Recording Times for Each Group

	First Record (T0)		Second Record (T1)		Third Record (T2)	
Group	Mean	SD	Mean	SD	Mean	SD
Control						
Right ear	12.59	3.71	-	-	9.23	3.49
Left ear	12.50	2.63	-	-	9.36	2.15
Total	12.55	2.15	-	-	9.30	2.58
Rapid maxillary expansion						
Right ear	31.43	14.84	15.23	7.75	15.30	8.97
Left ear	29.40	11.25	17.73	7.76	16.07	9.40
Total	30.42	11.20	16.48	6.73	15.68	8.52
Ventilation tube						
Right ear	29.91	15.48	22.94	13.46	13.28	4.66
Left ear	33.81	10.78	26.59	9.32	15.59	5.85
Total	31.86	10.97	24.77	10.36	14.44	4.63

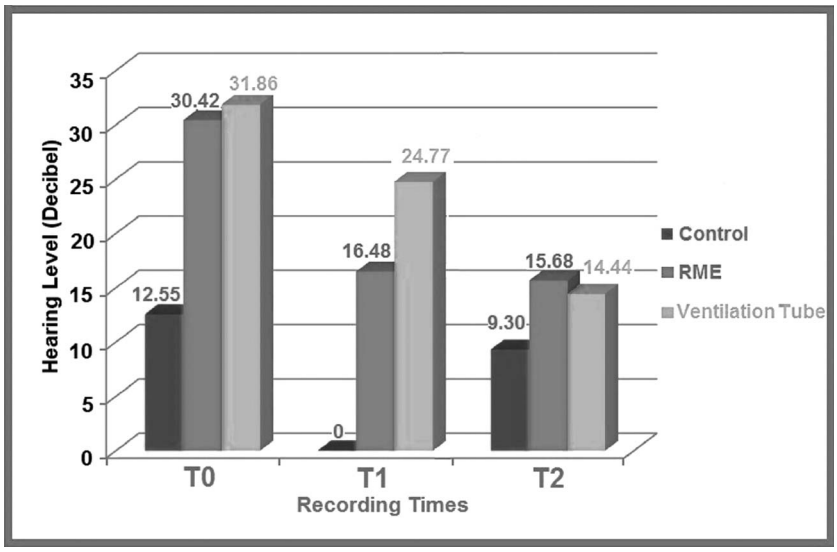

Figure 4. Hearing thresholds of each group at different recording times.

constriction and no treatment. In this way, spontaneous resolution of the OME could also have been compared or taken into account. Ethical considerations did not allow postponement of the treatment of patients with OME with or without maxillary constriction for scientific purposes, subjects without orthodontic and/or rhinologic problems formed the control group.

The findings of the present study show that the hearing thresholds decreased significantly up to 14–15 decibels after RME and remained stable. This means that skeletal and soft tissue expansion induced by the palatal separation forces affected the nasomaxillary complex, palatal shelf, tubal dilator muscles, nasopharyngeal hard and soft tissue architecture, and Eustachian tube dysfunction.

In some studies, hearing improvements of 2–6 decibels have been reported after RME.[7] Hearing improvements observed in these studies were less than the improvement observed in our study. Different patient selection criteria may be a reason for this disagreement. These studies[7] were carried out on the subjects without OME, but our sample consisted of children with OME.

Supporting our results, De Stefano et al.[8] and Villano et al.[9] found hearing threshold improvements of approximately 15 and 19 decibels after RME in children with recurrent otitis media.

We observed a gradual lowering of hearing thresholds in the ventilation tube group. Mair et al.[12] showed a gradually lowering of hearing thresholds after ventilation tube placement in patients with secretory otitis media. Browning et al.[13] emphasized that natural resolution of OME over led to improved hearing in subjects. Other long-term studies[14,15] have reported similar hearing improvements in subjects who had undergone ventilation tube placement.

When net changes were considered, it is obvious that hearing thresholds decreased significantly more in the RME and ventilation tube groups (15–17 decibels) than in the control group (3 decibels); whereas the improvements in hearing levels were insignificant between the RME and ventilation tube groups. This means that these two treatment approaches produced approximately the same improvements in hearing thresholds. The decrease in hearing threshold up to 3 decibels observed in the control group was temporary in nature and may result from seasonal allergies.

The rationale for inserting a ventilation tube is to improve ventilation, pressure regulation and re-pneumatization in the middle ear by aiming to recover Eustachian tube dysfunction in the long term.[1,7] Strong

Table 3. Results of Repeated Measure Analysis of Variance Test Explaining the Significances in Variance Analyses in Each Group

	T0	T1	T2	Comparison of Means		
Group	Mean	Mean	Mean	T1-T0	T2-T1	T2-T0
Control	12.55	-	9.30	-	-	**
Rapid maxillary expansion	30.42	16.48	15.68	***	NS	***
Ventilation tube	31.86	24.77	14.44	***	**	***

** $P < .01$; *** $P < .001$; NS indicates not significant.

Table 4. Results of Repeated Measure Analysis of Variance Test Showing Intergroup Comparisons of Total Changes in Hearing Thresholds (T2-T0)

		Rapid Maxillary Expansion Group (II)	Ventilation Tube Group (III)	Comparison of Groups		
Control Group (I)	Mean	Mean	Mean	I-II	I-III	II-III
Total changes in hearing thresholds	–3.25	–14.73	–17.42	**	***	NS

** $P < .01$; *** $P < .001$; NS indicates not significant.

scientific evidence supports the use of ventilation tube for treatment of OME and Eustachian tube dysfunction in children.[1,4] It can produce a 62% decrease in effusion prevalence.[4]

It is well documented that the Eustachian tube plays a role in management related to otitis media and Eustachian tube dysfunction.[1] A clinically normal Eustachian tube has three important functions in relation to the middle ear: pressure regulation, clearance (drainage), and protection.[1] In these respects, a ventilation tube fulfills two of these physiologic functions: pressure regulation and clearance of middle-ear secretions. However, the protective function of the Eustachian tube is impaired by ventilation tube insertion.[1] Regaining the pressure regulation and clearance functions of the Eustachian tube provided by ventilation tube placement may result in healthier middle ears and thus this recovery explains why most important hearing improvements occurred in children undergoing ventilation tube placement.[1]

RME appliances expand the narrowed maxillary arches in the transverse direction by rapidly separating the midpalatal suture and concomitantly splitting the maxillary halves.[16,17] Thus, RME causes dentofacial and craniofacial changes.[1]

These orthopedic changes can produce a new environment for oronasalpharyngeal and Eustachian tube functions. This new environment can produce favorable effects in these anatomic structures. In this respect, hearing improvements after RME may be explained by several reasons.

First, RME may result in normal functioning of the Eustachian tube. The tensor veli palatine (TVP) and levator veli palatine (LVP) muscles originate at or near the pharyngeal orifice of the Eustachian tube and end in the soft palate.[18] Active opening of Eustachian tube is mainly accomplished by the medial portion of TVP muscle, called the "dilator tuba muscle," and the LVP muscle may help to dilate the most anterior part of the tube.[18] Rapid separation of the hard and soft tissue palate may stretch the TVP and LVP muscles due to the close anatomic relationships between them. The relationship between the TVP muscle and middle-ear aeration and tubal function was shown by several types of surgical alteration of this muscle.[19] Neel et al.[20] showed that hearing was restored to normal levels by additional ventilation of the middle ear in patients with middle-ear effusion.

Second, RME causes hard and soft tissue changes in the stomatognathic system, and the changes RME produces in the mouth, nasal cavity, oropharynx, and nasopharynx will modify the soft tissue architecture overlying the bony structures of the nasomaxillary complex.[21]

RME widens the nasal airway dimensions, and this widening will not only improve nasal air flow and natural physiologic function but will also decrease upper respiratory infections, nasal allergy, respiratory morbidity, and otitis media,[6] which are the most common causes of hearing loss.[1]

Third, improved nasal breathing, reduced or cutoff mouth breathing (switching from nasal breathing to mouth breathing), and normalization of upper airway functions after RME may facilitates normal breathing and produce favorable effects on mouth microflora, although the role of RME on breathing mode remains unclear.[22]

Cazzolla et al.[23] found that RME may strongly reduce the pathogenic aerobic and facultative anaerobic microflora in the oropharynx after normalization of the upper airway functions and may reduce the risk of respiratory infections.

CONCLUSIONS

- Hearing thresholds decreased significantly in the RME and ventilation tube groups (15–17 decibels) after the observation period (T2); but at the first month (T1), the RME group showed better improvement than the ventilation tube group (13.94 decibels in RME group and 7.09 decibels in the ventilation tube group).
- RME produced the same outcome as ventilation tube placement: release of otitis media and improvement of hearing thresholds (levels).
- RME should be preferred as a first treatment option for children with maxillary constriction and resistance OME.

REFERENCES

1. Bluestone CD, Klein JO. Otitis media in infants and children. 4th ed. Hamilton, Canada: BC Decker; 2007.
2. Browning GG, Rovers MM, Williamson I, Lous J, Burton MJ. Grommets (ventilation tubes) for hearing loss associated with otitis media with effusion in children. *Cochrane Database Syst Rev*. 2016;(10):CD001801.
3. Zielhuis GA, Rach GH, van den Broek P. The natural course of otitis media with effusion in preschool children. *Eur Arch Otorhinolaryngol*. 1990;247:215–221.
4. Kuo CL, Tsao YH, Cheng HM, et al. Grommets for otitis media with effusion in children with cleft palate: a systematic review. *Pediatrics*. 2014;134:983–994.
5. Rudolph AM. *Pediatrics*. 16th ed. New York: Appleton-Century-Crofts; 1977.
6. Kiliç N, Oktay H. Effects of rapid maxillary expansion on nasal breathing and some naso-respiratory and breathing problems in growing children: a literature review. *Int J Pediatr Otorhinolaryngol*. 2008;72:1595–1601.
7. Kilic N, Kiki A, Oktay H, Selimoglu E. Effects of rapid maxillary expansion on conductive hearing loss. *Angle Orthod*. 2008;78:409–414.
8. de Stefano A, Baffa C, Cerrone D, et al. Management of recurrent otitis media with rapid maxillary expansion: our experience. *B-ENT*. 2009;5:13–17.
9. Villano A, Grampi B, Fiorentini R, Gandini P. Correlations between rapid maxillary expansion (RME) and the auditory apparatus. *Angle Orthod*. 2006;76:752–758.
10. Memikoglu TU, Işeri H. Effects of a bonded rapid maxillary expansion appliance during orthodontic treatment. *Angle Orthod*. 1999;69:251–256.
11. American Academy of Family Physicians, American Academy of Otolaryngology-Head and Neck Surgery, American Academy of Pediatrics Subcommittee on Otitis Media With Effusion. Otitis media with effusion. *Pediatrics*. 2004;113: 1412–1429.
12. Mair IW, Fjermedal O, Laukli E. Air conduction thresholds and secretory otitis media: a conventional and extra-high frequency audiometric comparison. *Ann Otol Rhinol Laryngol*. 1989;98:767–771.
13. Browning GG, Rovers MM, Williamson I, Lous J, Burton MJ. Grommets (ventilation tubes) for hearing loss associated with otitis media with effusion in children. *Cochrane Database Syst Rev*. 2010;(10):CD001801.
14. MRC Multicentre Otitis Media Study Group 1. Adjuvant adenoidectomy in persistent bilateral otitis media with effusion: hearing and revision surgery outcomes through 2 years in the TARGET randomised trial. *Clin Otolaryngol*. 2012;37:107–116.
15. Hong HR, Kim TS, Chung JW. Long-term follow-up of otitis media with effusion in children: comparisons between a ventilation tube group and a non-ventilation tube group. *Int J Pediatr Otorhinolaryngol*. 2014:78:938–943.
16. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. *Am J Orthod*. 1970;58: 41–66.
17. Ceylan I, Oktay H, Demirci M. The effect of rapid maxillary expansion on conductive hearing loss. *Angle Orthod*. 1996; 66:301–307.
18. Magnuson B. Physiology of the Eustachian tube and middle ear pressure regulation. In: Jahn AF, Santos-Sacchi J, eds. *Physiology of the Ear*. 2nd ed. San Diego, CA: Singular/ Thomson Learning; 2001:75–101.
19. Cantekin EI, Phillips DC, Doyle WJ, Bluestone CD, Kimes KK. Effect of surgical alterations of the tensor velipalatini muscle on eustachian tube function. *Ann Otol Rhinol Laryngol*. 1980;89(suppl):47–53.
20. Neel HB, Keating LW, McDonald TJ. Ventilation in secretory otitis media: effects on middle ear volume and eustachian tube function. *Arch Otolaryngol*. 1977;103:228–231.
21. Laptook T. Conductive hearing loss and rapid maxillary expansion. Report of a case. *Am J Orthod*. 1981;80: 325–331.
22. Compadretti CG, Tasca I, Alessandri-Bonetti G, Peri S, D'Addario A. Acoustic rhinometric measurements in children undergoing rapid maxillary expansion. *Int J Pediatr Otorhinolaryngol*. 2006;70:27–34.
23. Cazzolla MP, Campisi G, Lacaita MG, et al. Changes in pharyngeal aerobic microflora in oral breathers after palatal rapid expansion. *BMC Oral Health*. 2006;6:2.