

Effects of Rapid Maxillary Expansion on Conductive Hearing Loss

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ABSTRACT

Objective: To test the null hypothesis that rapid maxillary expansion (RME) with a rigid bonded appliance has no effect on conductive hearing loss (CHL) in growing children.

Materials and Methods: Fifteen growing subjects (mean age 13.43 ± 0.86 years) who had narrow maxillary arches and CHL participated in this study. Three pure-tone audiometric and tympanometric records were taken from each subject. The first records were taken before RME (T1), the second after maxillary expansion (T2) (mean = 0.83 months), and the third after retention (mean = 6 months) and fixed appliance treatment (approximately 2 years) periods (T3). The data were analyzed by means of analysis of variance (ANOVA) and least significant difference (LSD) tests.

Results: Hearing levels of the patients were improved and air-bone gaps decreased at a statistically significant level ($P < .001$) during active expansion (T2–T1) and the retention and fixed appliance treatment (T2–T3) periods. Middle ear volume increased in all observation periods. However, a statistically significant increase was observed only in the T2–T3 period. No significant change was observed in the static compliance value.

Conclusions: The hypothesis is rejected. RME treatment has a positive and statistically significant effect on both improvements in hearing and normal function of the eustachian tube in patients having transverse maxillary deficiency and CHL.

KEY WORDS: Rapid maxillary expansion; Hearing loss

INTRODUCTION

The stomatognathic system consists of those parts of the head, neck, and upper respiratory area concerned with the osseous, muscular, ligamentous, fascial, and nervous system. This system consists of 27 bones including the maxilla and mandible.¹ In recent years, great attention has been given to the total stomatognathic system. One of the most interesting topics in this subject is the association between the treatment of transverse maxillary deficiency and the recovery of functions such as the auditory one.

Rapid maxillary expansion (RME) is a well-established

technique for the correction of transverse discrepancies of the maxillary arch. RME has been routinely used for the treatment of transverse maxillary deficiency, posterior crossbites, crowding, abnormal breathing pattern,^{2–4} and conductive hearing loss (CHL) in growing children having maxillary constriction.^{5–9}

Although long-term studies give more meaningful data than the short-term ones, only two papers in the literature evaluated the long-term effects of maxillary expansion on CHL.^{10,11} In short-term studies evaluating the relationships between RME and CHL, Laptok,⁵ Hazar et al,⁶ Timms,⁸ and Ceylan et al⁹ reported that hearing levels improved in growing subjects. In another study performed on 25 subjects having recurrent serous otitis media and CHL, Villano et al¹² found that a functional improvement occurred in all patients at the end of the retention period of 8 months. In all of these studies, tooth-borne RME appliances were used to expand the maxillary arch.

In a recent and long-term study, Kilic et al¹¹ carried out semirapid maxillary expansion (SRME) with tooth-tissue borne appliances, and observed that hearing levels and middle ear functions were improved after an active expansion period, and that the improve-

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Accepted: July 2007. Submitted: May 2007.

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Table 1. Mean and Standard Deviation of Pure-Tone Thresholds at Different Speech Frequencies (Decibel) (N = 15)

Frequency, Hz	First Record		Second Record		Third Record	
	Mean	SD	Mean	SD	Mean	SD
250						
Right ear	30.33	7.90	25.33	7.90	20.67	8.63
Left ear	29.00	10.39	25.67	7.76	22.33	8.62
500						
Right ear	21.00	7.12	19.00	8.06	17.00	7.75
Left ear	22.00	9.02	19.67	8.34	15.67	9.80
1000						
Right ear	15.67	8.20	12.00	8.62	9.00	4.31
Left ear	14.33	7.53	12.33	6.78	9.67	5.81
2000						
Right ear	11.00	6.60	9.00	4.31	8.00	3.68
Left ear	12.00	6.21	7.67	6.23	8.33	4.88

Table 2. Mean and Standard Deviation of Air-Bone Gaps at Different Speech Frequencies (Decibel) (N = 15)

Frequency, Hz	First Record		Second Record		Third Record	
	Mean	SD	Mean	SD	Mean	SD
500						
Right ear	19.33	7.29	17.33	7.84	15.00	7.07
Left ear	19.00	7.61	17.00	8.19	13.33	8.38
1000						
Right ear	14.67	6.40	11.33	6.94	8.33	4.08
Left ear	13.67	7.43	12.33	6.78	9.33	4.95
2000						
Right ear	9.67	5.50	8.00	3.68	6.67	4.50
Left ear	11.33	5.81	7.67	6.23	7.33	4.17

ments in hearing remained relatively stable during the long-term observation period. It has been claimed that tooth-tissue borne appliances with occlusal acrylic coverage produce more skeletal expansion than that of the others.¹³⁻¹⁵

Hearing levels of patients in the previous studies have been assessed by means of pure-tone audiograms, whereas tympanometry is a sensitive measure of the tympanic cavity and eustachian tube.¹⁶ Thus, tympanometric records should be included with the studies investigating the changes in hearing.¹¹ Tympanometric evaluations were used only in two studies. One of them was a short-term evaluation of RME¹² and the other¹¹ was related to the long-term effects of SRME.

In the literature, there is no study evaluating the long-term effects of tooth-borne or tooth-tissue borne RME appliances on CHL by means of audiometric and tympanometric records. The purpose of this study is to investigate the long-term effects of RME with acrylic bonded appliances on CHL using both audiometric and tympanometric records.

MATERIALS AND METHODS

This study included 15 patients (12 female and 3 male) who underwent RME at the Department of Orthodontics, Faculty of Dentistry, Ataturk University, Erzurum, Turkey. Each patient had severe maxillary width deficiency, bilateral crossbite, and a deep palatal vault. The age range of the subjects was 11.25 years to 14.83 years, and the mean age was 13.43 ± 0.86 years.

Hearing levels of each patient was evaluated by an otorhinolaryngologist by means of pure-tone audiograms and tympanograms before RME. The design of the acrylic bonded appliance used in the present study and its activation program during RME has been described by Memikoglu and Iseri.¹⁷ RME appliances were activated twice a day, one turn in the morning and one in the evening until adequate expansion was achieved. The same appliance was used as a removable retention plate during the retention period.

Hearing levels of the patients was classified according to the air-bone gap values.^{18,19} Hearing losses were rated minimal in five patients, mild in eight patients, and moderate in two patients. Tympanometric and pure-tone audiometric records were taken from each patient at three different times under standard conditions in a room isolated from outside sounds. The first records were taken before RME (T1), the second records at the end of expansion (T2) (mean = 0.83 months), and the third records at the end of the retention period of 6 months and fixed appliance treatment of approximately 2 years (T3).

All audiometric records were evaluated by an otorhinolaryngologist and pure-tone thresholds for each patient were determined. The thresholds at the speech frequencies of 250, 500, 1000, and 2000 Hz were obtained separately for each ear. The air-bone gaps at the frequencies of 500, 1000, and 2000 Hz were also recorded. Static compliance values and middle ear volumes were determined from the tympanometric records.

Statistical Analysis

Descriptive statistics of the hearing levels and air-bone gaps at the investigated frequencies and of the tympanometric measurements for each ear were calculated for each measurement period. The data were analyzed by analysis of variance. The least significant difference (LSD) test was also applied to reveal between which periods the changes in the measurements were significant.

RESULTS

Tables 1 and 2 summarize the mean values and the standard deviations of the pure-tone thresholds and

Table 3. Mean and Standard Deviation of the Middle Ear Volume and Static Compliance Value (cc)

Parameters	First Record		Second Record		Third Record	
	Mean	SD	Mean	SD	Mean	SD
Middle ear volume						
Right ear	1.81	0.62	1.97	0.56	2.86	0.49
Left ear	1.76	0.73	1.90	0.52	2.80	0.54
Static compliance value						
Right ear	0.76	0.92	0.74	0.74	0.91	0.74
Left ear	0.67	0.63	0.68	0.57	0.79	0.50

air-bone gaps at different speech frequencies for each ear. Mean and standard deviation of the tympanometric measurements are shown in Table 3. The results of the variance analyses testing the changes at the hearing levels, middle ear volumes, and static compliance values are summarized in Table 4. The results of the LSD test, applied to explain the significances in variance analysis, are presented in Table 5.

As indicated in Tables 1, 2, and 4, the hearing levels were improved and the air-bone gaps were decreased in all frequencies at statistically significant levels ($P < .001$). According to the results of the LSD test (Table 5), the improvements in hearing levels and the decreases in air-bone gaps occurred during the active widening period (T1–T2), and the healings continued during the retention and fixed appliance treatment periods (T2–T3).

Middle ear volume a little increased at a statistically insignificant level during the widening period (T1–T2).

During the last observation period (T2–T3), middle ear volume increased from 1.93 to 2.83 and this increase has high significance ($P < .001$) (Tables 3 through 5).

Slight and insignificant changes were observed in the static compliance values during the T1–T2 and T2–T3 periods (Tables 3 through 5).

DISCUSSION

Maxillary constriction and concomitant posterior crossbite is perhaps one of the most common dento-skeletal problems encountered clinically,²⁰ and this constriction may affect some functions of the stomatognathic system.¹² A possible association between CHL and maxillary constriction has been previously reported in the literature.^{5,8,21} According to Fingeroth,²² maxillary deficiency frequently results in a decreased nasal permeability with mouth breathing, and within this environment a CHL may develop. Impaired eustachian tube functions may cause pathologic changes in the middle ear that in turn can lead to hearing loss and/or other complications such as otitis media.^{23,24}

RME appliances expand the narrowed maxillary arches in a transverse direction by rapid separation of the midpalatal suture, and concomitant separation of the maxillary halves.³ Except for the mandible, the maxilla is the largest bone of the face and it forms most of the lateral walls of the nasal cavity.²² The effects of RME are not limited to the upper jaw because the maxilla is connected with many other bones,⁹ and thus RME causes not only dentofacial, but also craniofacial changes.^{2,3}

Table 4. Summary of the Results of Variance Analyses Applied to Hearing Levels, Air-Bone Gaps, Middle Ear Volumes, and Static Compliance Values

Parameters Factors	Hearing Level		Air-Bone Gap		Middle Ear Volume		Static Compliance Value	
	F Value	P Value	F Value	P Value	F Value	P Value	F Value	P Value
Recording time	16.835	.000	11.303	.000	27.988	.000	0.389	.679
Frequency	85.377	.000	38.157	.000				
Ear (right-left)	0.005	.944	0.009	.926	0.218	.642	0.357	.552
Recording time × frequency	0.659	.683	0.311	.871				
Recording time × ear	0.035	.966	0.002	.998	0.002	.998	0.017	.983
Frequency × ear	0.008	.999	0.304	.738				
Recording time × frequency × ear	0.277	.947	0.258	.905				

Table 5. Results of Least Significant Difference (LSD) Test Explaining the Significances in Variance Analyses

Parameters	First Record (T1)	Second Record (T2)	Third Record (T3)	Comparison of the Means		
	Mean	Mean	Mean	T1–T2	T2–T3	T1–T3
Hearing level (dB)	19.42	16.33	13.83	*	*	***
Air-bone gap (dB)	14.61	12.27	10.00	*	*	***
Middle ear volume (cc)	1.79	1.93	2.83	NS	***	***
Static compliance value (cc)	0.72	0.71	0.85	NS	NS	NS

* $P < 0.05$; *** $P < .001$; NS indicates not significant.

Rapid separation of the maxilla commonly has been carried out with a conventional Hyrax appliance or an acrylic bonded expander. Bonded RME appliances with occlusal acrylic coverage have been reported to have certain advantages such as greater skeletal expansion, more parallel movement of the anchor teeth and the two maxillary halves, and thus long-term stability over the conventional expanders.^{13,15} In the present study, the RME procedure was carried out with an acrylic bonded appliance.

It has been accepted that audiograms objectively measure the hearing levels in subjects with normal hearing or in patients who had hearing loss such as a conductive loss, a sensorineural loss, or both.²⁵ Pure-tone audiograms measure air- and bone- conduction thresholds and present them on a graph across all the hearing frequencies.²⁵ The differences between these two thresholds provide an estimate of the magnitude of the conductive component of an existing hearing loss and is called the air-bone gap.²⁵

Tympanometry provides useful quantitative information about the presence of fluid in the middle ear, mobility of the middle ear system, and ear canal volume.²⁶ It also provides information about the functions of the middle ear in general.²⁷ Tympanometric records give also valuable data regarding eustachian tube dysfunctions.²⁶ Tympanometry has found widespread clinical usage because it provides a noninvasive way to determine the pressure in the middle ear cavity.²⁷ Measurement of the static compliance of the tympanic membrane and of the volume of the tympanic cavity are beneficial to determine the changes in the stiffness of the tympanic membrane, reduction of the middle ear effusion, and volumetric changes in the middle ear cavity.^{26,27}

The results of the present study indicated that statistically significant improvements in hearing levels and the decreases in the air-bone gaps occurred during both observation periods (T1–T2 and T2–T3). The results were stable during the long-term evaluation (approximately 2.5 years). There is a general consensus in the relevant literature that hearing levels improved after maxillary expansion.^{5,6,8–12} However, there are different findings in literature for hearing levels after the expansion. Contrary to our findings, Laptook⁵ and Hazar and co-workers⁶ in short-term studies, and Kilic et al¹¹ and Timms⁸ in long-term studies observed that the improvements in hearing after maxillary expansion did not increase, but were retained during the ongoing days. In addition to these authors, Ceylan et al⁹ and Taspinar et al¹⁰ reported that the results obtained after expansion reverted to some extent during the retention period.

These disagreements could be explained by the different situations. A difference with the authors^{17,18}

showed the relapse tendency could be explained by the difference in the appliances used. In the present study, the RME was carried out with a bonded acrylic appliance, but the others used a conventional Hyrax appliance. Acrylic coverage of the bonded appliances would direct the force vector to the center of resistance of the maxilla, leading to more bodily movement^{13,15,28} and long-term stability over the conventional expanders.^{13,15} Long-term stability of the conventional RME appliances was evaluated by several authors,^{3,29} and the results showed that an inevitable relapse occurred during the retention period of the widening procedure. The relapse tendency for Hyrax appliances may explain the different results in hearing observed in our and other studies.

The authors^{5,6,8} who found relatively stable results after RME also used different expanders. Two of these papers^{5,6} are case reports, and their results include only subjective responses to RME treatment. In addition, they are short-term results of the procedure. The third paper was published by Timms,⁸ in which the subjects were also evaluated by subjective methods, and the results were based upon the response of the patients. These different evaluation methods may explain the disagreement.

Different expansion schedules may be a factor for the difference with the results of Kilic et al.¹¹ Although Kilic et al¹¹ carried out maxillary expansion with a bonded appliance and their observation period was similar to that of the present study, they applied a semirapid maxillary expansion procedure, and their widening period lasted 3.4 months. It has been accepted that an adaptation process of soft and hard tissues in the circummaxillary structures occurs during and after an active expansion period of SRME.^{11,15}

Important improvements in hearing occurred in the first observation period (T1–T2) of this study, and this improvement continued during the second period (T2–T3). Similar results were reported in a recent paper of Villano et al.¹² These authors observed important improvements in hearing of all patients, and stated that correction of palatal anatomy by RME influenced the muscular function of tubal ostia and allowed a normal activity of the tympanic membrane and the auditory apparatus.

In the present study, middle ear volumes of the patients increased a little during the widening period, while considerable increments of improvement were observed during the long-term observation period (Tables 3 through 5). Kilic et al¹¹ found important increases in this measurement during the expansion, retention, and fixed appliance treatment periods. The disagreement observed in the expansion period may be a result of the difference in the expansion periods of the two studies, which lasted 3.4 months in the SRME

procedure. Villano et al¹² observed that the tympanograms showed significant recovery in some patients after RME, but in all cases after the retention period of 8 months.

Anatomical connections between the middle ear and nasopharynx may explain the effect of RME on hearing improvements. The middle ear is the part of a functional system composed of the nasopharynx, the eustachian tube (anteriorly), and the mastoid air cells (posteriorly).²³ The tensor and levator veli palatini muscles originate at or near the pharyngeal orifice of the eustachian tube and end in the soft palate.³⁰ Active opening of the eustachian tube is mainly accomplished by the medial portion of the tensor veli palatine muscle. This division of the muscle has been named the "dilator tuba muscle." The levator veli palatine muscle may help to dilate the most anterior part of the tube.³¹ The functions of the eustachian tube are to ventilate the middle ear and to protect the middle ear from excessive sound pressure and nasopharyngeal secretions.²³

The relationship between the tensor veli palatine muscle and middle ear aeration and tubal function was shown by several types of surgical alteration of this muscle.³² In a clinical study, Neel et al³³ have shown that middle ear volume increased progressively and hearing was restored to normal levels by additional ventilation of the middle ear in patients with middle ear effusion.

After RME, the stretching that occurs in the levator and tensor veli palatini muscles opens the pharyngeal orifice of the eustachian tube, thus allowing air to enter or leave the middle ear. By allowing air to pass through the tube, pressures on either side of the tympanic membrane are balanced and the ossicular chain can vibrate freely and function normally.^{5,23,34} It has been suggested that RME applications restored the eustachian tube dysfunctions, ventilated the tympanic cavity, and improved CHL.^{5,6,9-12}

In addition, the skeletal changes occurred during an RME procedure in the mouth, nasal cavity, oropharynx, and nasopharynx will modify the soft-tissue architecture overlying the bony structures of the nasomaxillary complex.^{5,35} Widening of the nasal airways will result in not only an improvement in nasal air flow and natural physiologic function, but also a decrease in upper respiratory infections, nasal allergy, respiratory morbidity, and otitis media.^{7,36} These are the most common causes of conductive hearing loss.^{10,23,37} In a recent study, Cazzolla et al³⁸ showed that RME may strongly reduce the pathogenic aerobic and facultative anaerobic microflora in the oropharynx and, when the upper airway functions are normalized, may reduce the risk of respiratory infections.

Based on the findings of the present study, it may

be said that the auditory function in patients with conductive hearing loss and maxillary constriction may be corrected through correction of the palatal anatomy with RME. This can influence the muscular function of the tubal ostia and allow normal activity of the tympanic membrane and the auditory system.

CONCLUSIONS

- Hearing levels of patients with CHL were improved and air-bone gaps decreased at a statistically significant level ($P < .001$) during active expansion (T2–T1) and the retention and fixed appliance treatment (T2–T3) periods.
- Middle ear volume increased in all observation periods. However, a statistically significant increase occurred only in the retention and fixed appliance treatment periods (T2–T3).
- Slight increases were observed in the static compliance values in all observation periods, but these changes were not statistically significant.
- RME procedure provides positive and stable effects on hearing and eustachian tube functions of growing children who have CHL and transverse maxillary deficiency.

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