International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Effects of Maxillary Expansion on the Ear: A Review

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Abstract
Rapid maxillary expansion is a commonly used treatment modality for the correction of maxillary transverse deficiency in cleft and non-cleft patients. Additional beneficial effects of rapid maxillry expansion includes improvement in nasal stenosis, abnormal breathing pattern and conductive hearing loss. The improvements in the hearing have been linked to the improved function of the two soft palatal muscles, the tensor veli palatini and the levator veli palatini muscles.
This study aims to explore the different studies which have evaluated the effects of rapid maxillary expansion on hearing in cleft and non cleft patients.

Keywords: Rapid maxillary expansion, conductive hearing loss, cleft lip and palate

Introduction
Rapid maxillary expansion (RME) is a therapeutic procedure that results in increase in the transverse dimensions of the maxillary arch. RME causes the posterior teeth and alveolar processes to move buccally[1]. According to a systematic review by Liu et al., in 2015 the mid palatal suture opens approximately 12–52.5 percent of the total screw expansion, but the study could not confirm whether the mid palatal sutural opening was parallel or triangular[2].
According to the Global Burden of Disease study the years lived with disability and hearing loss was found to be the fourth leading cause globally[3]. Hearing loss is classified into: sensorineural hearing loss and conductive hearing loss (CHL). Sensorineural hearing loss is characterized by lesions in the cochlea or involves the eight cranial nerve[4]. CHL on the other hand is an auditory disorder with elevated air-bone conduction thresholds.
CHL can be classified according to the severity and types of the physical changes imposed on the outer or middle ear. In normal hearing the air and bone conduction thresholds interweave. In mild CHL the air-bone gap is 20–30 dB, in moderate CHL the air-bone gap is 30–45 dB and in severe CHL the air-bone gap is 45-60 dB[5].
Patients who suffer from maxillary constriction are 3.5 times more likely to suffer from CHL[6]. Children with cleft lip and palate present with a significantly higher prevalence of otitis media with effusion as

compared to non-cleft patients. Aberrant levator veli palatini muscle positioning, as well as an abnormal fusion with the tendon of the tensor veli palatini muscle, predisposes them to otopathologies[7].

Proper hearing system, anatomical and physiological integrity, auditory pathway maturity and sound stimulation are essential for the acquisition and development of verbal language[8]. Maxillary expansion has been shown to improve hearing in patients with CHL. According to a systematic review by Fagundes et al., in 2017 based on nine studies, maxillary expansion results in hearing level improvement by 2-19 dB[9].

This manuscript aims to describe and provide insights into the effects of maxillary expansion on hearing in cleft and non-cleft patients.

Methods of hearing assesment

Audiometry

Pure tone audiometry is considered as the gold standard test in the objective assessment of hearing levels and pure tone thresholds at different frequencies[9]. Audiometer devices are used to quantitatively measure the air conduction and bone conduction pure tone thresholds. According to the American National Standards Institute Specification for audiometer devices, there are four types of audiometers, with Type 1 having the maximum features and Type 4 having the least features. Type 1 audiometer is a full-featured diagnostic audiometer. Type 1 audiometer device contains earphones, bone vibrators, loudspeakers, masking noise, etc and can be considered as a full-featured diagnostic audiometer. A Type 4 audiometer on the other hand is a simple screening machine with earphones, with no other special features[10].

The test involves the delivery of sound by an earphone at different frequencies, and the hearing levels are assessed for each ear separately. Bone conduction thresholds are assessed by placing a vibrator on the skull, which results in the stimulation of cochlea directly, without involving the outer and the middle ear. A comparison of the air conduction and bone conduction thresholds provides an estimate of the status of the conductive or sensory hearing loss.

Tympanometry

Tympanometry is an objective test of acoustic admittance of the middle ear as a function of air pressure in a sealed ear canal. The test involves the introduction of varying air pressure in the ear canal, which causes the tympanic and ossicular chain to stiffen. As the air pressure is varied in the ear canal, the admittance flowing into the middle ear is decreased, resulting in more sound pressure remaining in the ear canal. The result is a tympanogram, with a normal tympanogram having a single clearly defined peak at near atmospheric pressure, which is represented as Type A[11]. Type B tympanogram has an abnormally low admittance with no discernible peak. Type C tympanogram has normal admittance, with a peak occurring at negative pressure.

Review of literature

Author/Year	Number of participants	Mean Age	Expansion appliance and expansion protocol	Method of hearing assessment	Results
Ceylan et al. 1996[11]	14	12.9 years	Hyrax appliance	Pure-tone audiograms (dB)	Hearing levels were improved from the

Author/Year	Number of participants	Mean Age	Expansion appliance and expansion protocol	Method of hearing assessment	Results
			Activation protocol: two turns per day		baseline (20.39 ± 11.78 dB) to post-RME (17.54 ± 12.59 dB, p value = .043). No differences were observed in the retention period (18.18 ± 6.83 dB)
Taspinar et al. 2003[5]	35	14.5 years	Hyrax appliance Protocol of activation: 3 times/d for 3 days; after midpalatal suture opening: 2 times/day until the complete elimination of the posterior crossbite	Pure-tone audiograms (dB)	There was an improvement in the hearing levels from baseline (24.45 ± 7.4 dB) to post RME (20.63 ± 7.08 dB) and end of retention period of 2 years(20.95 ± 7.13 dB, p value = .001).
Villano et al. 2006[12]	25	7.24 years	Hyrax appliance Activation protocol: three times a day for 7 to 14 days until the need of each patient.	Pure-tone audiograms (dB), Tympanometry (dB), and Video-otoscopy	There was an improvement in the hearning levels from baseline (31.6 ± 5.76 dB) to post RME (26.9 ± 4.33 dB p value =.001). The hearing levels also showed improvement after the retention period (17.36 ± 2.11 dB, p value = .0001)
Cozza P 2007[13]	24	7 years	Butterfly expander Activation protocol: three times a day	Pure-tone audiograms	Improvement in conductive hearing loss and hearing levels after retention period

Author/Year	Number of participants	Mean Age	Expansion appliance and expansion protocol	Method of hearing assessment	Results
Kilic et al. 2008[14]	15	13.4 years	Hyrax appliance Activation protocol: twice a day.	Pure-tone audiograms (dB) Tympanometry(dB)	Hearing levels were improved from baseline (19.42 ± 7.87 dB) to post RME (16.33 ± 7.25 dB, p value = .05) and after fixed appliance treatment (16.33 ± 7.25 dB) and end of treatment (13.83 ± 6.68 dB, p value = .001).
Kilic et al. 2008[15]	19	13.4 years	Hyrax appliance Activation protocol: one turn twice a day during the first 5–7 days; after suture opening, two turns a day, three times a week, until result in 2 mm of overexpansion.	Pure-tone audiograms (dB) and tympanometry (dB)	Hearing levels were improved during the active widening period (20.66 ± 8.85 dB to 15.69 ± 6.25 dB, p value = .001), and the results remained stable during the retention and fixed appliance treatment periods (end of retention: 16.32 ± 6.67 dB and after treatment: 16.52 ± 6.68).
De Stefano et al. 2009[16]	27	7 years	Hyrax appliance Activation protocol: one-quarter turn in the morning and another quarter turn in the evening till the	Pure-tone audiograms (dB) and tympanometry (dB)	An improvement in mean values of air-bone gaps was recorded before (32.03 dB) and after removal of RME appliance (12.91 dB), which was

Author/Year	Number of participants	Mean Age	Expansion appliance and expansion protocol	Method of hearing assessment	Results
			upper molar palatal cusps were in contact with the lower molar buccal cusps		stable after 12 mo (12.91 dB).
Micheletti et al. 2012[17]	18	8.1 years	Haas expander Activation protocol: Two turns every day (0.5 mm/d), during 15–20 days.	Pure-tone audiograms (dB) and tympanometry	There were no significant variations on the hearing levels in periods studied (p value = 0.05).
Kilic et al. 2016[18]	26	RME group- 10.07 years Control - 8.34 years	Hyrax appliance Activation protocol: Two times a day: one-quarter turn in the morning (0.2 mm) and one in the evening (0.2 mm).	Pure-tone audiograms (dB)	In the RME group, hearing threshold decreased approximately 15 dB after maxillary expansion (before RME: 30.42 ± 6 11.20 dB and after RME: 16.48 ± 6.73 dB, p value = .001) and remained relatively stable during the observation period (after 10 mo: 15.68 ± 8.52 dB).
Singh H et al. 2019[19]	26	11.1 years	Hyrax Activation: RPE 0.5 mm/day 7–14 days	Pure-tone audiograms (dB) and tympanometry	Rapid maxillary expansion treatment produced a significant increase in the hearing levels and middle ear volumes of all non-cleft and

Author/Year	Number of participants	Mean Age	Expansion appliance and expansion protocol	Method of hearing assessment	Results
					bilateral cleft lip palate patients with normal hearing levels and with mild conductive hearing loss.
Fatima et al. 2022[20]	6	8.1 years	Hyrax expander Daily activation of one-quarter turn per day for a period of 15-20 days (0.25 mm per day).	Pure-tone audiograms (dB) and tympanometry	There were no significant changes in the hearing levels on the audiometry test after RME on the cleft side (p-value = 0.51) and the noncleft side ear (p-value = 0.26). No significant changes were observed in the middle ear volume on the tympanometry test after RME on the cleft side (p-value = 0.09) and the noncleft side ear (p-value = 0.28).

Discussion

Several studies have evaluated the effects of RME on hearing loss, with the first attempt by Laptook, who observed an improvement in hearing in a patient after 1.5 weeks of expansion[21]. The hearing level improvement was retained till 1.5 years of treatment[21]. Timms[22], and Taspinar et al[5]., observed considerable hearing improvement after RME. Ceylan et al[11]., found that hearing levels were significantly improved during the active expansion period, but there was a relapse during the retention period. In a recent and long-term study, Kilic et al[14]., carried out RME and observed the hearing level changes for a period of two years. There was an imrovement in the hearing levels after RME and the improvement was stable after two years. According to a systematic review by Fagundes et al., the authors stressed that more controlled and randomized studies were necessary to investigate this issue further[9]. In a recent study by

Singh et al., which evaluated the effects of RME on hearing and speech production in bilateral cleft lip and palate patients, there was a significant improvement in the hearing levels in children with normal hearing and mild conductive hearing loss[19]. In a study by Fatima et al., which evaluated the effects of RME on hearing in unilateral cleft lip and palate patients, there were no improvements in the hearing levels and middle ear volume after RME and six months retention period[20].

Physiologically, the levator veli palatini and the tensor veli palatini opens and closes the orifice of the eustachian tube resulting in humidification and lubrication of the inner ear. If the palatal arches are high and the maxillary arch is constricted, these muscles insert in a stretched, hypo functional, and cramped state resulting in obstruction in the mucus deflection. The mass of mucus and the virulent exudates leads to recurrent serous otitis media.

Active opening of eustachian tube is mainly accomplished by the medial portion of tensor veli and levator veli palatini muscles[23]. RME brings the muscular ends near the tubal ostia, which may result in an improvement in the opening and closing of the eustachian tube[12]. Rapid separation of the palate may stretch the tensor veli and the levator veli palatini muscles resulting in the equalisation of air pressure on either side of the tympanic membrane.

Secondly, RME widens the nasal airway dimensions, which results in natural physiologic function and reduction in upper respiratory infections, nasal allergies, respiratory morbidity, and otitis media, which are the most common causes of hearing loss[14].

Among the cleft lip and palate patients hearing levels have been shown to improve in bilateral cleft lip and palate patients[19], while in another study contradictory results were produced in unilateral cleft lip and palate patients[20].

This could be due to the abnormal eustachian tube opening mechanism in the cleft palate patients. The tubal lumen of the eustachian tube is less C-shaped in cleft palate patients and the insertion angle of the tensor veli palatini muscle into the cartilage has been found to be narrower than in normal patients, which results in less efficient pull force leading to eustachian tube dysfunctions[24].

In conclusion, maxillary expansion may result in hearing improvement in growing children and adolescents. Although, more studies with longer follow ups and control groups are needed to reach a more conclusive evidence.

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