Original Article

Correlations between Rapid Maxillary Expansion (RME) and the Auditory Apparatus

Andrea Villanoa; Barbara Grampi; Roberto Fiorentinib; Paola Gandinic

ABSTRACT

Objective: To evaluate the effects of rapid maxillary expansion (RME) on conductive hearing loss and maxillary constriction.

Materials and Methods: A total of 25 subjects (15 girls and 10 boys, aged between 6 years 8 months to 8 years 2 months) with conductive hearing loss and maxillary constriction were studied. Audiogram, tympanogram, and video-otoscopy were used to investigate the anatomical and physiological modifications of the bony and muscular structure of the maxilla and the auditory apparatus. The records were taken before maxillary expansion (T0), after expansion (7–14 days; T1), and after the retention period (8 months after expansion; T2).

Results: After expansion, the audiometric records indicated an improvement in hearing levels for higher frequencies but not for lower ones. After the retention period, there was a functional improvement in all patients for all frequencies. The recovery of the tympanic membrane’s elasticity occurred only after retention, as shown by the standard model tympanogram, which was still flat after expansion.

Conclusions: The auditory function in patients with conductive hearing loss may be corrected through correction of the palatal anatomy, which influences the muscular function of the tubal ostia and allows a normal activity of the tympanic membrane and the auditory apparatus. Positive effects on conductive hearing loss are possible additional benefits of RME treatment, but this does not indicate that patients with conductive hearing loss without an accompanying maxillary constriction should consider this as a treatment approach.

KEY WORDS: Rapid maxillary expansion; Hearing loss

INTRODUCTION

The dental literature discussing correlations and connections between the stomatognathic system and other apparatuses is constantly increasing. One of the most interesting topics is the correction of skeletal and/or dental transverse problems of the maxilla. Orthopedic and orthodontic results are often associated with unexpected therapeutic effects on other apparatuses, such as the auditory one. The limited data in the literature on this specific topic suggests the possibility of improving hearing levels by correcting the palatal anatomy.

In this literature, there are studies that attest to the positive effect of palatal expansion in improving hearing. Braun observed a correlation between hearing loss and maxillary constriction. Rudolph stated that tubal malfunction was more frequently seen in children who had extremely high palatal arches, as well as malformations of the palate and nasopharynx, that may predispose them to otitis media. According to Laptook, the orthopedic effect of rapid maxillary expansion (RME) helps to improve hearing levels in patients with maxillary deficiency. The effect of the expansion on the palatal and nasopharyngeal tissues improves the functioning of the pharyngeal ostia of the eustachian tubes. Laptook reported that patients’ hearing improved within the first 10 days and also noted that this improvement continued during the active phase of treatment.

Gray found that recurrent serous otitis media decreased remarkably in subjects treated with RME.
According to Timms\textsuperscript{5–7} hearing levels improved after expansion. Hazar et al\textsuperscript{8} reported a significant improvement in hearing within 4 weeks of RME treatment. According to Fingeroth,\textsuperscript{9} maxillary expansion may improve hearing loss related to middle ear and eustachian tube problems. Ceylan et al\textsuperscript{10} performed RME on 14 patients (11 girls and 3 boys) aged between 10 years 4 months and 16 years 9 months (average age 12 years 11 months ± 1 year 9 months) with conductive hearing loss and maxillary deficiency. They found that hearing levels had significantly improved during the active expansion period; and although they observed some relapse in the hearing level after the retention period (about 4.5 months), it did not significantly affect the overall results obtained.

Pirelli et al\textsuperscript{11} selected 15 patients (9 girls and 6 boys, average age 11.5 ± 1 year) who showed malocclusion characterized by maxillary crowding and transverse constriction. These patients had some breathing difficulties and hearing loss. They all underwent RME to correct the transverse discrepancy and to evaluate a potential improvement in hearing. After expansion, 9 subjects presented normal hearing while 6 of them showed a slight improvement. After expansion, 13 subjects showed normal levels of hearing and 2 subjects showed a slight hearing loss.

All of these studies reported on the short-term effects of rapid palatal expansion on hearing loss, but there is a lack of information on the long-term results. A report by Taspinar et al\textsuperscript{12} evaluated these effects over a 2-year period on 35 subjects and reported that RME had a positive effect on hearing levels. At the end of the retention period, the improvement tended to reverse, but the reversal was of a clinically small magnitude. On the other hand, in 26% of the patients, improvements in hearing levels were not statistically significant.

Our study originated from an analysis that showed certain patients, those with clinical symptoms of recurrent serous otitis resistant to antibiotic therapy and with conductive hearing loss, have a small maxilla with a high palatal vault and transverse discrepancy. The fact that a transverse deficiency may be a preexisting or a predisposing cause to this kind of alteration was investigated. A change in the palatal anatomy causes alterations in the relationship between the internal peristafilini muscles or palatal levators,\textsuperscript{13} the external peristafilini muscles or tensors of the soft palate, and the bones where they insert into the palate itself.

Physiologically, the peristafilini (levators and tensors) are muscles that open and close the pharyngeal ostia of the eustachian tube\textsuperscript{13} and clear its internal parts of the mucus secreted to humidify and lubricate the inner tube. If the palatal arches are high and the transverse dimension is deficient, these muscles insert in a stretched, hypofunctional, and cramped state, obstructing the mucus deflection. The mass of mucus and the virulent exudates lead to recurrent serous otitis. To restore the correct palatal anatomy, increasing the transverse dimension, brings the muscular ends near the tubal ostia. This may cause an improvement in tonicity and in the physiological opening and closure of the tubal ostia, facilitating the mucus outlet.

To test this theory, the possibility of modifying the anatomy of the palatal vault through orthopedic-orthodontic therapy was investigated. The effects on muscular activity were studied, as well as the reduction of otitis and the improvement of hearing levels. Therefore, RME was performed to improve auditory function through anatomic and muscular change of the tube and improvement of air perfusion at its entrance.

### MATERIALS AND METHODS

Among the patients needing rapid palatal expansion for orthodontic reasons, 25 subjects (15 girls and 10 boys) between 6 years 8 months and 8 years 2 months of age were selected. All selected subjects reported recurrent serous otitis with conductive hearing loss (Table 1).

After their visit to the otolaryngologist, all subjects underwent a thorough clinical-anamnestic investigation and a series of instrument examinations. Apart from the usual orthodontic diagnostic records necessary for the orthodontic treatment, some otolaryngologic examinations were obtained to better investigate the auditory problem:

- An audiogram to examine the auditory function;
- A tympanogram to analyze the variations in elasticity of the tympanic membrane related to the pressure changes in the external auditory tube; and
- A video-otoscopy, which allows the instrumental observation of the external auditory tube and the tympanic membrane.

All the subjects’ parents were well informed and knowledgeable about the risks and benefits of the examinations, and they gave their consent for the additional procedures their children had to undergo.

The 25 selected subjects underwent RME. The appliance had two or four bands, and the screw was ad-

### TABLE 1. Demographic Data

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<tr>
<th>Age, y</th>
<th>Mean ± SD (n)</th>
<th>Min–Max</th>
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<td></td>
<td>7.24 ± 0.58 (25)</td>
<td>6.1–8.2</td>
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<table>
<thead>
<tr>
<th>Gender, n (%)</th>
<th>Female</th>
<th>Male</th>
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<tr>
<td></td>
<td>15 (60%)</td>
<td>10 (40%)</td>
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justed three times a day for 7 to 14 days until the necessary expansion for each subject was accomplished.

The tympanogram and the audiogram were performed before the palatal expansion (T0) and after the expansion (7–14 days; T1) to evaluate all changes in the anatomy and physiology of the bony and muscular structure of the maxilla and the auditory apparatus. The video-otoscopy, because of its complexity and high costs, was performed only at the beginning (T0) and at the end of the retention period (T2).

During treatment, no anti-inflammatory, antibiotics, or serous fluidifying medicine were given. The 25 subjects showed a conductive hearing loss before expansion (T0) as confirmed by instrument analysis.

(a) The audiogram highlighted a conductive and not a sensorineural hearing loss (Table 2).

This allowed the exclusion of any ear anatomical malformation and suggested the presence of serous fluid, which partially reduced the elasticity of the tympanic membrane causing the perception of a muffled or almost an absence of sound at lower frequencies at T0.

The hearing loss was greater for frequencies between 250–1000 Hz, quite normal between 1000–2000 Hz, and less between 2000–4000 Hz. All subjects started to perceive sounds starting at 30 dB and above. Normal hearing was recorded between 0 dB and 20 dB. Hearing loss was defined as mild from 20–30 dB, moderate at 30–40 dB, and maximum at 60 dB, more precisely between 250 Hz and 1500 Hz.

At T0, 11 subjects could hear in both ears at 40 dB, while 8 subjects could hear at 40 dB in the right ear and 30 dB in the left ear; 2 subjects had a threshold of 50 dB in the right ear and 30 dB in the left one; 3 subjects could hear at 30 dB in the right ear and at 40 dB in the left one; and 1 subject could hear frequencies of 50 dB in both ears.

(b) At T0, the tympanogram was flat in all subjects in both ears, confirming the short elasticity of the tympanic membrane and suggesting that hearing loss was due to serous secretions that could not flow away from the inner part of the membrane (Table 3).

At T0, the video-otoscopy revealed the presence of a thick mucous exudate in variable quantities at the pharyngeal entrance of the tube (Figure 1).

The statistical evaluation was made through the variance analysis, which allows highlighting of the test differences at different frequencies over time. The six different cases drawn from the measurement at the three frequencies for both ears were analyzed. For each case, a comparison test of measurements over time (T0, T1, and T2) was then calculated.
RESULTS

After palatal expansion (T1), the same instrument analysis used for the diagnosis revealed the following results (Table 2):

(a) The audiogram at 250–1000 Hz did not register any improvement, apart from four subjects where a slight improvement was recorded as follows: one subject had an improvement in both ears, and three subjects in one ear only. For frequencies between 1000–2000 Hz, mild improvements were recorded in all subjects who were normal at 2000–4000 Hz. This data might suggest that the 2 weeks during which the appliance was activated were not sufficient to allow the complete elimination of serous secretions from the internal part of the ear.

(b) The tympanogram was flat in almost all subjects apart from four subjects: one subject revealed a slight improvement in the right ear, another subject in the left ear, and two subjects in both ears (Table 3).

After the retention period (T2), both the tympanogram and the audiogram were carried out for the third time to evaluate the long-term effect of the maxillary orthopedic therapy.

(a) The audiogram revealed total recovery of the auditory function and that the decibel and hertz values were similar to the normal values in all subjects in both ears (Table 2).

(b) After retention (T2), the tympanogram showed a standard model, highlighting the total recovery of the tympanic membrane’s elasticity. For this reason, its function was perfectly normal (Table 3). After retention (T2), the entrance of the tube was free of serous secretions, as shown by the video-otoscopy (Figure 2).

The results of the variance analysis demonstrated that in the six different situations the comparisons were significantly different than those at T0 and T1 at 250–1000 Hz. The same results were present when considering only three frequencies. If $P > F < .0001$, the estimated parameter has a statistically significant value. The contrast and $P > F$ show the differences between the test’s results two by two and, even in this case, the differences were always significant (Table 4).

DISCUSSION

RME is used to correct maxillary constriction with posterior crossbites. It also improves respiration by increasing the width of the nasal passages. Brown suggested that maxillary constriction, which is one of the causes of nasal stenosis, can affect the eustachian tubes and the middle ear, and result in hearing loss. In animals, rapid palatal expansion results in cranioskeletal displacements, and skeletal changes that occur in the mouth, oropharynx, nasal cavity, and nasopharynx tend to modify the soft tissue architecture overlying these bony structures.

Some patients affected with hearing loss also have a history of recurrent upper respiratory tract infections. The general improvement in nasal physiology after RME minimizes the drying of the pharyngeal mucosa and decreases the upper respiratory tract infections and otitis media, which is a common cause of conductive hearing loss.

Progressive deafness occurs through an increase in the tympanic membrane concavity as a result of pressure loss. Chronic otitis media is an example of conductive deafness because in this disorder air conduction is impaired. With RME, palatal and pharyngeal soft tissues can be modified and tubal ostia may function more normally. As a result, air passes through the tube, and pressures on both sides of the tympanic membrane are balanced. Thus, the tympanic cavity and the ossicular chain can vibrate freely and function normally.

Anatomical correlations between the middle ear and nasopharynx may explain the action of RME in hearing improvements. The middle ear is connected to the nasopharynx by the eustachian tube, which in turn communicates with the nasal cavities and the oropharynx. As RME has certain effects on the nasal cavity and palate, it may also affect the eustachian tube functions. In addition, the tensor veli palatini muscle may...
affect hearing improvements. Furthermore, the fact that this muscle lays at or near the eustachian tube orifices and enters into the soft palate plays an important role in the opening of the eustachian tube orifices.\(^9\)

The eustachian tube connects the tympanic cavity to the nasal part of the pharynx, and its orifice lies on its respective lateral nasal pharyngeal wall. Physiologic obstruction of the eustachian tube comes from the tensor veli palatini muscles at their origins. It keeps the tube from opening in response to negative pressure in the middle ear. Negative pressure in the middle ear, by itself, may be another cause of tubal malfunction. If the tube is blocked, air in the tympanic cavity is absorbed into the mucosal cells (and may at times be replaced with serous or mucous secretions) with loss of pressure, increasing concavity of the tympanic membrane, and progressive deafness.\(^1,21\)

The peristafilini muscles open and close the pharyngeal ostia of the eustachian tube\(^13\) and clear its internal parts of the mucus secreted to humidify and lubricate the inner tube. If they are hypofunctional, the mucus deflection is impaired and the mass of mucus and the virulent exudates lead to recurrent serous otitis.

The results of this study highlight that all subjects selected for palatal expansion and with conductive hearing loss showed incomplete improvement at instrument examination. At T1, the membrane was able to recover its elasticity, and the improvement caused by the decongestion of the tube was considerable at the audiometric test for frequencies between 1000 Hz and 4000 Hz, but not for the lower ones (250–1000 Hz).
Hz). After 8 months, a complete recovery of the auditory function from the lowest (250 Hz) to the highest values (4000 Hz) occurred.

This improvement, which is more significant in the long term, attests to the necessity of a certain period of time to eliminate the serous fluid after the anatomical improvement in the tubal entrance. The tympanogram data, which certify the tympanic membrane’s elasticity, support this assumption. After RME, the tympanogram is still flat in almost all subjects despite the normal functioning of the tubal ostia. After retention (T2), the tympanogram shows its standard model because the tympanic membrane is no longer prevented from vibrating by serous fluid and the edema.

The present study demonstrates that improvements in hearing after RME occur after the expansion period for higher frequencies but not for lower ones, and after the retention period (8 months) for both higher and lower ones.

These data do not agree with those of Ceylan et al. These authors report a statistically significant improvement after the active treatment, but a decrease after the retention period. This relapse is not considered relevant by the authors and may be caused by soft tissue relapse.

Timms criticized this study because the subject selection was made more on the malocclusion than on hearing loss, and it registered only ranges and means instead of individual levels of hearing loss. The study by Taspinar et al allows a longer evaluation, too. The first audiometric recording was taken before expansion and the second after satisfactory expansion of the maxillary arch was obtained (approximately 18 days after). After that, the RME was fixed in the mouth and used as a retention device for 6 months, and the third recording was taken at the end of this period. At the end of this 6-month period, a rigid transpalatal arch with an extension throughout anterior teeth was inserted and used for 2 years. At the end of this period, the fourth registration was taken. In this study, the long-term stability may be assumed to be due to the rigid retention after expansion, which was not used in the other studies. This study was different from Taspinar’s study because it did not show long-term results, which will be the subject of further research.

From the analysis of the limited literature on this topic, it can be assumed that in patients with conductive hearing loss with maxillary constriction, palatal expansion may improve the auditory function leading to more physiological activity of the pharyngeal ostia of the eustachian tube.

### CONCLUSIONS

- The results of this study confirm and highlight the possibility of improving the auditory function of patients with conductive hearing loss through the correction of palatal anatomy.
- Positive effects on conductive hearing levels are considered as possible additional benefits of RME treatment but do not indicate that patients with conductive hearing loss should consider RME as a treatment approach without an accompanying maxillary constriction.

### REFERENCES

12. Taspinar F, Üçüncü H, Bishara SE. Rapid maxillary expander...
14. Dirks DD, Morgan DE. Auditory function tests. In: Bailey BJ,
15. Wertz RA. Skeletal and dental changes accompanying rapid
16. Haas AJ. Rapid expansion of the maxillary dental arch and
nasal cavity by opening the midpalatal suture. Angle Orthod.
1961;31:73–90.
17. Haas AJ. The treatment of maxillary deficiency by opening
18. Gardner GE, Kronman JH. Cranioskeletal displacements
caused by rapid palatal expansion in the rhesus monkey.
19. Starnbach HK, Cleall JF. The effects of splitting the mid-
1964;50:923.
20. Hershey HG, Stewart BL, Warren DW. Changes in nasal
airway resistance associated with rapid maxillary expan-
eustachian tube function in children with secretory otitis me-
dia. Evaluations at tube insertion and at follow up. Int J Pe-
diatr Otorhinolaryngol. 2000;52(2):131–141.