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Effects of rapid maxillary expansion on the airways and ears—a pilot study

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SUMMARY The aim of this prospective study was to describe the morphological and functional changes of the upper airways and the middle ears after rapid maxillary expansion (RME). Thirteen patients comprised the original study sample, of these three patients dropped out. Of the remaining 10 subjects, seven (two females, five males; average age, 8.7 years) underwent orthodontic RME with a Hyrax screw and three (one female, two males; average age, 8.3 years) served as the controls. Inclusion criteria for the study group were a uni- or bilateral crossbite with the evidence of a maxillary deficiency. Exclusion criteria were acute or chronic respiratory disease, allergies, cleft lip and palate, or absence of adenoids. An ear, nose, and throat (ENT) examination, lateral cephalometry, anterior rhinomanometry, tympanometry, and posterior rhinoscopy were carried out for each child at baseline (E1) and after 6 months (E2). Descriptive statistics were calculated for all diagnostic variables and correlations between the study and control group were evaluated.

Rhinomanometry showed a correlation ($r=0.57$) between the size of the nasal pharyngeal area and nasal airflow, but only at 150 daPa. The size of the adenoids measured on the lateral cephalograms was correlated with the endoscopic findings. The size of the adenoids remained the same after RME. Patients with maxillary constriction had the largest adenoids and showed a negative pressure in the middle ear. However, this was reduced after RME.

The results suggest a possible impact of maxillary deficiency on otorhinological structures. RME may lead to otorhinological changes. Further interdisciplinary investigations are needed to corroborate these findings.

Introduction

The transverse dimension of the maxilla is defined by the maxillary skeletal base and the inclination of the buccal segment surrounded by alveolar bone (Solow, 1980). A reduced transverse dimension of the maxilla and a dental posterior crossbite are commonly associated with higher nasal resistance (Löfstrand-Tideström *et al.*, 1999). According to Helm (1986), transverse occlusal discrepancies are manifest in 9.4 per cent of Danish boys and 14.1 per cent of Danish girls.

It has been postulated that higher nasal resistance is associated with mouth breathing and various dentofacial developmental aspects involving the dentition and the skeleton (Bushey, 1972; Linder-Aronson *et al.*, 1986; Meredith 1987; Usumez *et al.*, 2003). In the English literature, the descriptive term *adenoid facies* has been used for at least a century (Proffit and Fields, 2000). Laptook (1981) supported this theory, describing in a case report, a syndrome. The characteristics of this skeletal development syndrome are a decrease in nasal permeability resulting from nasal stenosis, elevation of the nasal floor, mouth breathing, bilateral dental maxillary crossbite along with a high palatal vault, and, due to an enlargement of the nasal turbinates, a decrease in nasal airway size.

Linder-Aronson *et al.* (1993) reported a significant increase in sagittal airway size and an almost significant improvement of the nasal airflow as well as a more labial position of the upper and lower incisors after adenoidectomy. The improvement of nasal airflow may have a positive effect on general development during childhood (Kurol *et al.*, 1998).

Orthodontic unilateral posterior crossbite correction may provide harmonious function and regular symmetrical transversal skeletal growth and development (Santos Pinto *et al.*, 2001). It may also alter the resting position of the tongue. In growing individuals, the two parts of the maxilla are connected by fibrous tissue in the mid-palatal region and in adults by bone. Rapid maxillary expansion (RME) separates the two parts of the maxilla in a transverse direction opening up a significant diastema between the two central incisors.

RME in the primary or early mixed dentition induces significant and effective long-term changes at the skeletal level (Thilander *et al.*, 1984; Da Silva Filho *et al.*, 2000; Baccetti *et al.*, 2001).

It has been a well and long known subjective phenomenon that RME facilities nasal airflow and hearing (Goddard, 1893; Schroeder-Benseler, 1913; Hershey *et al.* 1976; Hartgerink *et al.*, 1987), although scientific investigations producing evidence-based data are missing.

To verify this hypothesis, which is mainly based on clinical experience, the purpose of this study was to investigate the morphological and functional effects of RME on the upper airways and middle ear in an interdisciplinary approach analysing diagnostic variables such as tympanometry, anterior rhinomanometry, posterior endoscopy, and cephalometry lateral headfilms.

Subjects and methods

The protocol was approved by the Ethical Committee of the Medical University of Vienna (EK-Nr.539/2004).

The original sample comprised 13 children (five females, eight males) registered at the Orthodontic Department of the School of Dentistry, Medical University of Vienna. The criteria for selection of the study group ($n = 9$; three females, six males) were a uni- or bilateral posterior crossbite with evidence of a maxillary deficiency and the indication for RME clinically judged by the examining orthodontist. The control group consisted of four children (two females, two males) with an adequate transverse dimension of the maxilla, but with other malocclusion patterns, which did not require the use of RME. The exclusion criteria for both groups were acute or chronic respiratory disease, allergies, cleft lip and palate, or absence of adenoids. The mean age of the study group was 8.7 ± 0.9 years and of the control group 8.3 ± 3.8 years.

The initial examination (E1) included the initial orthodontic records, i.e. dental casts, lateral head film, panoramic radiograph, extra- and intra-oral photographs, and an endoscopic posterior rhinoscopy. An ear, nose, and throat (ENT) examination, to exclude pathological findings, anterior rhinomanometry and tympanometry were conducted by an otolaryngologist. RME was carried out with an acrylic splint cemented to the primary posterior teeth. A Hyrax-type screw (Palatinal split screw type S®, Forestadent Bernhard Förster GmbH, Pforzheim, Germany) connected the acrylic parts of both sides (Figure 1). The activation protocol was 0.25 mm/day for 2 weeks, until overcorrection of the transverse relationship of 3 mm was seen. The acrylic splint remained *in situ* for retention for 6 months. The second examination (E2), immediately after the retention period, included the following diagnostic records: lateral cephalometry, endoscopic posterior rhinoscopy, anterior rhinomanometry, and tympanometry. In all instances, the ENT and orthodontic examinations were carried out by the same specialists (HS and SC), respectively.

Sagittal airway size was measured on the lateral cephalograms as described by Trotman *et al.* (1997) as the distance between the highest aspect of the cranial part of the soft palate and the posterior pharyngeal wall. The size of the adenoids and the dimension of the pharyngeal airway were analysed as defined by Linder-Aronson (1970), Linder-Aronson and Henrikson (1973), and Hibbert and Whitehouse (1978) (Figure 2A–C).

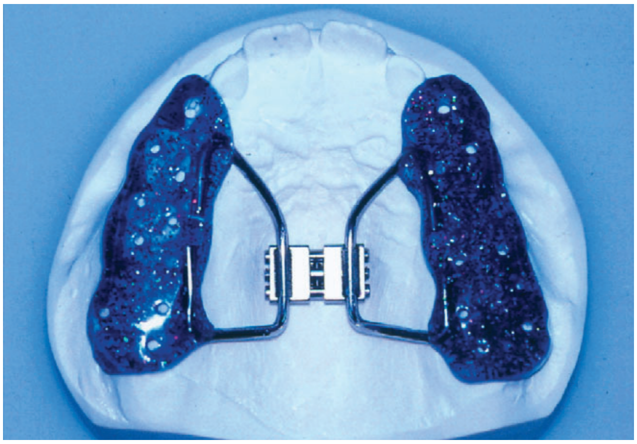

Figure 1 The acrylic rapid maxillary expansion device used in this study.

Posterior rhinoscopy was carried out with an endoscope (Hopkins II Optik 90°, 4 mm, 18 cm, Karl Storz GmbH & Co., Tuttlingen, Germany). The patients were allocated to three groups according to the size of their adenoids in relation to the Eustachian tube ostium: group 1—small, group 2—intermediate, and group 3—large (Figure 3A–C).

For anterior rhinomanometry, an Atmos Rhinomanometer 300® (Atmos Medizintechnik GmbH & Co., Lenzkirch, Germany) and a facemask were used. With this method, the rate of airflow and the pressure gradient between the nasopharynx and the nostrils can be measured simultaneously with a plastic tube in the oral cavity and a facemask. The nasal flow and the resistance were recorded separately for the right and left sides and combined for both sides (75, 150, and 300 daPa, respectively). Narrowing or widening of the nasal passages influenced the outcome.

Tympanometry was performed with an Impedance Audiometer AZ26® (Interacoustics, Assens, Denmark) to measure the pressure (daPa) in the middle ear and the elasticity of the tympanic membrane as compliance (ccm).

Statistical analysis

For descriptive statistics, mean values and standard deviations (SDs) of all diagnostic variables were computed. Pearson's coefficient of correlation was used for evaluating correlations between the study and the control group. All calculations were made with Excel for Windows (Microsoft®, Redmond, Washington, USA).

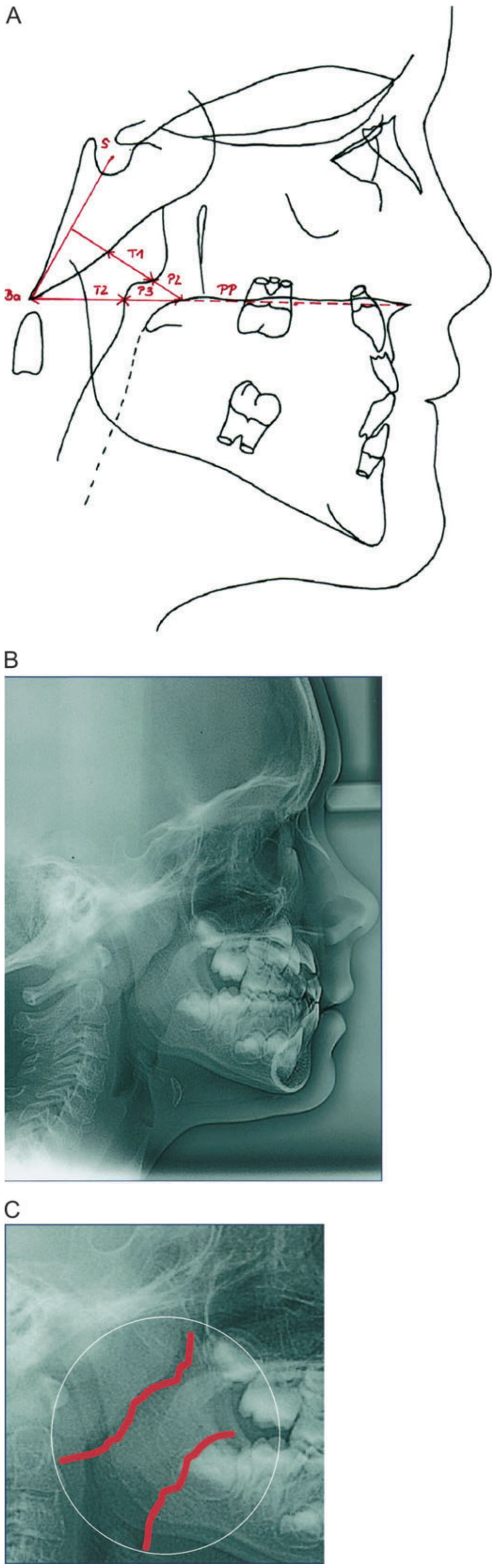

Figure 2 A, B, and C: Lateral cephalometric analysis: sagittal airway size as described by Trotman *et al.* (1997). T1 and T2 describe the sagittal dimension of the adenoids and P2 and P3 the sagittal dimension of the pharynx. T1 and P2 are measured on a line from posterior nasal spine to midway to the basion-sella line. T2 and P3 are measured on a line from the posterior nasal spine to basion.

Results

The drop-out rate was three out of 13 patients. Two patients (two females) in the study group were excluded, one due to a poorly fitting mask during rhinomanometric examination and the second due to non-compliance during posterior rhinoscopy. A male patient in the control group failed to attend the ENT appointment. The study group comprised of six males and one female and the control group of one male and two females.

The mean interval between E1 and E2 was 6.2 ± 0.7 months. All data were evaluated by an experienced orthodontist (SC) and ENT specialist (HS), respectively.

In the ENT evaluation at E1 except for enlarged adenoids, no additional pathologies in the upper airways influencing nasal airway resistance were found.

Cephalometric analysis

The study group showed a small pharyngeal space. The mean value for P2 was 11 mm and for P3 14 mm. In both groups, the pharyngeal space increased from E1 to E2 (Table 1). No statistically significant difference in the size of the adenoids was found between the study and control group.

After maxillary expansion and retention for 6 months, the adenoidal tissue was unchanged (delta T2 = −1.67 mm) in the study group, but insignificantly reduced in the control group.

Posterior rhinoscopy

In the study group, three children had small, one child intermediate, and three large adenoids. In the control group, the adenoids were rated as intermediate in two children and small in one. A comparison of the three groups showed good correlation with the adenoid size measured on the lateral cephalogram at both E1 and E2. In one patient in the study group, the adenoidal tissue appeared to be reduced after RME.

Anterior rhinomanometry

No statistically significant correlation was found between restricted nasal permeability and maxillary constriction. A comparison of the cephalometric data and nasal airflow showed a direct correlation between the size of the pharyngeal space (P2, P3) and nasal airflow (Pearson index $r = 0.57$) but only at a pressure difference of 150 daPa (Table 2). The measured size of the adenoids at E1 and E2 and the nasal airflow were weakly correlated (Pearson index $r = -0.36$).

Tympanometry

While a negative pressure with a mean value of −48.86 daPa (SD 22.90, minimum −112, maximum −28) in the

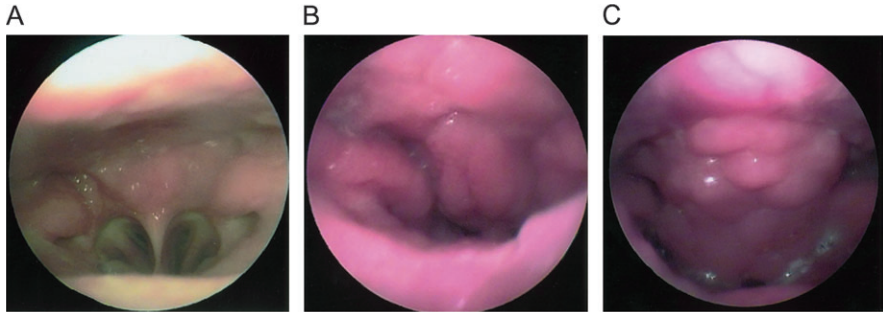

Figure 3 Endoscopic appearance of the size of adenoidal tissue. (A) Small: the adenoidal tissue has no contact with the structure of the torus tubaris. (B) Intermediate: the adenoidal tissue is in contact with the structure of the torus tubaris, but the opening of the Eustachian tube is clearly identifiable. (C) Large: the hypertrophic tissue covers the opening of the Eustachian tube.

middle ear was found in children with a transverse deficiency compared with the control subjects, who showed a mean value of −38.67 daPa (SD 19.10, minimum −92, maximum −8), all measurements were within the normal range. In the study group, the peak of the curve biased to positive from E1 to E2. Within this group, patients with large adenoids showed the greatest improvement (Table 3). A comparison of the change in nasal airflow and improvement in middle ear pressure showed a significant linear correlation (Pearson index $r=-0.80$) between the improvement in middle ear pressure and the decrease in nasal airflow.

Table 1 Cephalometric values (mean ± standard deviation) for the sagittal dimensions of the adenoids (T1, T2) and pharynx (P2, P3) and sagittal airway size (mm) before treatment and after rapid maxillary expansion (RME).

	Before treatment		Mean change after RME	
	Study group, $n=7$	Control group, $n=3$	Study group, $n=7$	Control group, $n=3$
T1	15.86 ± 5.19	17.33 ± 2.49	+0.86	0.0
T2	26.00 ± 7.46	26.33 ± 1.25	+0.43	−1.67
P2	11.00 ± 4.99	13.33 ± 2.05	+0.29	+0.33
P3	14.86 ± 6.81	20.33 ± 1.70	+0.14	+2.67
Sagittal airway size	6.71 ± 5.23	10.33 ± 0.47	−0.43	+0.33

Discussion

Impairment of middle ear ventilation, as indicated by negative pressure values in tympanometry, attenuates sound conduction by stiffening the tympanic membrane: sound is absorbed to a lesser degree, and a larger sound fraction is reflected. Persistence of insufficient middle ear ventilation results in mucinous hypersecretion *en vacuo* leading to chronic serous otitis media. Although being ultimately sterile, chronic serous otitis media may partly emanate from poorly resolved acute otitis. Apart from causing conductive hearing impairment, chronic serous otitis media may lead to structural damage of the tympanic membrane, as atrophic scars or retraction pockets, both precursors of cholesteatoma. Impaired middle ear ventilation also promotes tubogenic spread of infection into the middle ears causing acute otitis media (Corbeel, 2007).

The tympanometric data in this study showed not only statistically significant differences between the study and control group but also a clinically relevant change from negative to positive values. However, the tympanometric data of all patients were within the normal range before and after RME. In the study group, the peak of the curve biased to positive from E1 to E2. The improvement in middle ear pressure may be attributable to a change in the muscular function of the soft palate after expansion (Timms, 1980). It was also found that the transversal distance of the pterygoid hamuli was increased after palatal expansion with a fixed expansion appliance (Timms, 1980). The increase in interhamular width was 58 per cent of that intermolar width, i.e. 3.0–7.0 mm. This magnitude of spatial change is reputed to have an impact on the function of the tensor veli palatini muscles as part of the physiologic obstruction of the Eustachian tube (Timms, 1997).

The transverse skeletal and morphological changes of the upper airways after RME have been investigated using different diagnostic methods such as postero-anterior cephalometric analysis, computed tomographic images, and acoustic rhinometry (Da Silva Filho *et al.*, 1995; Ceroni Compadretti *et al.*, 2006; Enoki *et al.*, 2006; Podesser *et al.*, 2007). In the present study bearing in mind the young age of the patients, a dose-intensive computed tomographic evaluation was avoided and the influence of RME on the pharyngeal airways regarding the nasal pharyngeal passage and the tubal function providing the middle ear ventilation were considered by means of posterior endoscopy and lateral cephalometry.

Clinical inspection of adenoids by an otolaryngologist depends on the child's co-operation. The results of this pilot study suggest that an assessment of adenoids on lateral cephalograms is sufficient and that the size of the adenoids can be easily measured. After the age of 5 years, an age-related decrease of the adenoidal tissue and an increase of the nasopharyngeal space have been described (Linder-Aronson and Leighton, 1983). Due to the small sample size and the young age of the patients in the present investigation, a relationship between the radiological criteria of the nasopharyngeal space and the age of the patient was not verifiable.

The measured sagittal airway size in the present study is in agreement with the results of Trotman *et al.* (1997). Their sample consisted of 207 children from 3 to 13 years of age. The mean sagittal airway size was reported to be 4.6 ± 2.9 mm on average, with a minimum distance of 0 mm and a maximum distance of 15.2 mm. The mean of 8.5 mm in the present study was 1 mm above the reported SD. The mean age of 8 years 7 months was within the SD of Trotman *et al.* (1997). The minimum distance of 2 mm and the maximum distance of 15 mm were also within the limits. The findings therefore do not support the conclusion that children with a posterior crossbite have a smaller airway size than an eugnathic population.

Riolo *et al.* (1974) analysed the cephalometric distance from basion to posterior nasal spine to find a correlation of the mean values with age and gender. However, the distances recorded in the present study group were lower than the means reported by Riolo *et al.* (1974). Only one patient was above the SD. The average value showed the absolute deviation from normal: at an average age of 8 years 8 months, the mean T2 + P3 was 40.86 mm. This implies that the space between the clivus and the posterior margin of the maxilla is reduced in patients with transverse constriction.

The hypothesis that the size of the adenoidal tissue diminishes after expansion was not confirmed by the cephalometric data (Picchi *et al.*, 1990). These rather showed an increase in size between E1 and E2. A reduction of the adenoidal tissue mass and a resultant increase in pharyngeal space were only observed in the control group.

Zapletal and Chalupova (2002), in a study of 192 patients aged between 2 and 19 years, found the average rhinomanometric results at a pressure difference of 150 daPa to correlate with body height. The flow was between 329 and 842 ccm/second. Those authors suggested a formula relating flow to age and gender allowing the means to be

Table 2 Comparison of the nasal airflow (ccm/s) at a pressure difference of 150 daPa and the size of the pharyngeal space (P2, P3; mm) measured on the lateral cephalograms before treatment.

Patient no.	Age (years)	Anterior rhinomanometry	Lateral cephalogram	
		ccm/s (pressure difference of 150 daPa)	P2 (mm)	P3 (mm)
1	8.5	136	3	6
2	7.3	296	9	10
3	8.3	332	15	22
4	9.3	84	11	13
5	10.5	320	15	18
6	9	224	6	9
7	8	300	9	26
8	8.8	268	13	22
9	9.9	244	16	21
10	6.5	184	11	18

Table 3 Tympanometric and endoscopic data of the study (SG) and control (CG) groups before treatment (E1) and at the second examination (E2).

Patient no.	Age (years)	E1			E2			Difference (E1 to E2)	
		Tympanometry		Posterior rhinoscopy	Tympanometry		Posterior rhinoscopy	Tympanometry	
		Pressure (daPa), right ear	Pressure (daPa), left ear	Adenoidal size	Pressure (daPa), right ear	Pressure (daPa), left ear	Adenoidal size	Pressure (daPa), right ear	Pressure (daPa), left ear
1 SG	8.5	−80	−28	Large	−60	−15	Large	+20	+13
2 SG	7.3	−64	−112	Large	0	−28	Large	+64	+84
3 SG	8.3	−28	−32	Small	−25	−30	Small	+3	+2
4 SG	9.3	−28	−28	Intermediate	−68	−28	Intermediate	−40	+0
5 SG	10.5	−56	−56	Small	−24	−24	Small	+32	+32
6 SG	9	−36	−48	Large	−32	−32	Intermediate	+4	+16
7 SG	8	−36	−52	Small	−112	−44	Small	−76	+8
8 CG	8.8	−92	−20	Intermediate	−84	−32	Intermediate	+8	−12
9 CG	9.9	−28	−36	Small	−24	−32	Small	+4	+4
10 CG	6.5	−48	−8	Intermediate	−52	−12	Intermediate	−4	−4

calculated for every age and gender. Nasal resistance is graded as slight, moderate, large, or very large.

According to the formula of Zapletal and Chalupova (2002), only one subject in the study group showed normal nasal flow, whereas all other patients had nasal obstruction. This disagrees with the ENT diagnoses, which did not reveal any nasal obstruction.

The reported positive findings of an improvement in nasal airflow resistance and hearing level after RME support the initial hypothesis underlying this study (Goddard, 1893; Schroeder-Benseler, 1913). The nasal airflow recorded after RME was 200 ccm/second at a pressure of 150 daPa. While the control group demonstrated an increased nasal airflow, the study group showed, on average, a reduction of 16.557 ccm/second. No correlation was apparent.

Instead of the expected improvement (Linder-Aronson, 1970), two patients showed a decrease in nasal flow after RME. This may be attributable to the wide range of rhinomanometric data. That improvement is only detectable in patients with severe restriction before treatment is another possible explanation. Seasonal swelling of the epithelium is an unlikely reason, as patients complaining of seasonal swelling were excluded from the study. The significant improvement of a poor nasal flow reported by White *et al.* (1989) after expansion was not proven by the present data.

Rhinomanometry has previously been used for evaluating the effects of RME (Timms, 1986; Kurol *et al.*, 1998; Enoki *et al.*, 2006). For the first time, tympanometry was combined with anterior rhinomanometry, posterior rhinoscopy, and cephalometric analysis for interpretation in this study.

Given the small sample size, a prospective study of at least 30 patients and controls will be needed to support the preliminary data.

One limitation of the study is the absence of inter- and intraobserver variability; however, all measurements were performed by an experienced orthodontist and when the results were inconclusive, an additional opinion was obtained.

Whether or not patients are candidates for adenoidectomy (Kim *et al.*, 1998) is decided by otolaryngologists or paediatricians. The findings of the present research indicate that, although the size of the adenoids did not decrease, an improvement in middle ear ventilation was achieved. Care should be taken at the first examination of a child to look for a potential posterior crossbite. Early palatal expansion carries a lower risk than adenoidectomy. The decision whether the adenoids should be removed or not also depends on the patient's age. Considering the risk of post-operative bleeding after tonsillectomy and adenoidectomy, critical judgement is required in the decision-making process. In addition, RME in young patients has a greater impact on skeletal changes and long-term stability (Melsen 1975, Melsen and Melsen 1982, Wertz and Dreskin 1977). This has been demonstrated by Taşpinar *et al.* (2003) using a similar retention protocol as in this study. They showed a stability rate of 75 per cent in hearing improvement 2 years after treatment. Thus, orthodontic treatment should be considered as a rational and reasonable approach.

Conclusions

The findings of this study show the following:

1. Patients with maxillary constriction and large adenoids had a negative middle ear pressure.
2. Expansion alleviated the negative middle ear pressure in all patients.
3. Maxillary constriction combined with malfunction of the Eustachian tubes may cause the negative pressure seen on tympanometry.
4. Large adenoids were only present in children with maxillary constriction.
5. The size of the adenoids and the nasopharyngeal space can be estimated from lateral cephalograms.
6. Nasal airflow and adenoid size did not improve after maxillary expansion.
7. The size of the nasopharyngeal space did not correlate with the measured nasal airflow.
8. Early crossbite correction can be expected to improve skeletal features and oronasal function.

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