Rhinofibroscopic and Rhinomanometric Evaluation of Patients with Maxillary Contraction Treated with Rapid Maxillary Expansion. A Prospective Pilot Study

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Objective: *The aim of this study was to evaluate through nasal fiber optic endoscopy and rhinomanometry the patency of upper nasal airways in patients treated with rapid palatal expansion* ***Study design***: *30 patients (12 males and 18 females) aged 7-11 years with transverse maxillary constriction underwent rhinomanometric and fiberoptic examination before (T0) and after rapid palatal expansion (T1).The amount of nasopharynx obstruction was quantified with reference to the full choanal surface. Nasal resistance was recorded separately for right and left sides, and combined for both sides. The differences in nasopharynx obstruction and in nasal resistance between T0 and T1 were statistically evaluated.* ***Results***: *The amount of nasopharynx obstruction significantly decreased after palatal expansion ($p<0.001$). Total nasal inspiration and expiration resistance significantly decreased at T1 ($p<0.001$). The reduction ranged between 0. 23 and 0. 66 Pa/cm^3/s for inspiration and between 0. 20 and 0,.58 Pa/cm^3/s for expiration. A statistically significant positive correlation existed between the T1-T0 differences in the amount of nasopharynx obstruction and the T1-T0 differences in expiration nasal airway resistance (Spearman's correlation coefficient rho = 0.38; p = 0.03).* ***Conclusions***: *Rapid maxillary expansion has an influence on nasal resistance and improves the patency of upper airways in patients with minor or moderate breathing problems.*

Key Words: *rapid palatal expansion, maxillary contraction, rhinomanometry, nasal obstruction, fiberoptic endoscopy.*

INTRODUCTION

Maxillary constriction or hypoplasia is one of the most frequently skeletal problems in the craniofacial region, with a prevalence ranging from 2.7% to 23.3% [1].

Transversal maxillary constriction is often associated with rhinologic as well as dental characteristics, such as decreased nasal permeability resulting from nasal stenosis, enlargement of nasal turbinates causing a decrease in nasal airway size, elevation of the nasal floor, mouth breathing, dental maxillary crossbite coincident with a high palatal vault. [2-7]

Accuracy in diagnosis is the first step for a correct approach to upper nasal airways impairments and their treatment. [8]

Rapid maxillary expansion (RME) is a common treatment to correct transverse maxillary deficiency. It is a distraction procedure that splits the mid-palatal suture to encourage the growth of the maxilla along the suture in a short period of time. The treatment is typically carried out with an appliance having an expansion screw welded to the bands on first molars [9].

Several studies have shown that RME while producing orthopedic and orthodontic corrections may also affect the geometry and function of the nasal cavity [10-18].

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Only a few studies have evaluated the RME naso-respiratory features, mainly through indirect methods such as: cephalometric evaluation, tympanometry, computational fluid dynamics. [19,20,21] Rhinomanometric examination of patients treated with palatal expander revealed reduction of nasal resistance, while cephalometric analyses showed an increase, of the nasopharyngeal space after palatal expansion. [22,23]

Rhinomanometry (RM) measures air pressure and rate of airflow during breathing, which are used to calculate nasal airway resistance. Active anterior RM, introduced by Coutade in 1902, is the most commonly used method, as it is usually well tolerated and it is easier for the patient to cooperate [24].

Nasal fiberoptic endoscopy is the procedure whereby a flexible fibreoptic bundle of glass fibres is introduced into nasal cavities, so that mucosa and turbinates conditions, dimensions of adenoid tissue, and septal deviations may be directly inspected. [25]

In the present investigation, for the first time, nasal fiber optic endoscopy and RM were combined in the evaluation of anatomy and physiology of upper nasal airways in patients treated with rapid palatal expansion. The objective of this study was to evaluate, through repeatable instrumental examinations, changes of the upper nasal airway before and after palatal expansion.

MATERIALS AND METHOD

The study protocol was preliminarily approved by the Ethical Committee of the University of Siena

A sample of 34 Caucasian children, between 7 and 11 years of age, in need of RME treatment was collected among individuals seeking orthodontic therapy at the Department of Orthodontics of the University of Siena. The following exclusion criteria were considered in selecting the sample: craniofacial disorders, acute or chronic respiratory disease, allergies, cleft lip and palate, absence of adenoids, prior or co-adjuvant orthodontic treatments or otorhinolaryngologic pharmacologic therapies.

As for inclusion criteria, all the selected subjects presented mixed dentition, uni- or bi-lateral posterior crossbite involving at least deciduous canines and permanent first molars. Of the initially selected subjects, 3 failed to return after initial records and 1 had the RME removed prematurely. Thereby, 30 subjects, 12 males and 18 females, were enrolled in the prospective study. The mean age of the study sample was 8.7 years with a standard deviation of 0.9.

After collecting parents' informed consent, the selected subjects underwent orthodontic as well as ear, nose, and throat (ENT) examinations (T0).Orthodontic records included lateral cephalometric radiograph, study models, extra oral front and profile photographs, intraoral photographs. An experienced ENT specialist performed nasal endoscopy and anterior RM. Endoscopy was accomplished using a flexible fiberoptic nasopharyngoscope, that, passing along the floor of the decongested nasal passage, was introduced into the nasopharynx under topical anesthesia. The amount of nasopharynx obstruction was quantified with reference to the full choanal surface and the following 4 grades were defined [26].

Grade 0 = 0-25% of choanal surface obstructed

Grade 1 = 25-50% of choanal surface obstructed

Grade 2 = 50-75 % of choanal surface obstructed

Grade 3 = 75-100 % of choanal surface obstructed

For anterior RM, an Atmos Rhinomanometer 300® (Atmos Medizintechnik GmbH & Co., Lenzkirch, Germany) and a face-mask were used. To perform rhinomanometry patients were asked

to wear a face mask, close their mouth and breathe only with the nose in accordance with the International Committee on Standardization of Rhinomanometry.

The rate of airflow and the pressure gradient between nasopharynx and nostrils were measured . Nasal resistance was recorded in Pa/cm^3/s. on the right and the left nostril. Measurements of both sided were then combined.

The resistance to passage of air considered as normal, in agreement with the literature, concerns values that go from 0.18 to 0.46 Pa / cm3 / s. We considered that values higher than those indicate a form of resistance as mild or moderate problem.[27]

RME was carried out with a Hyrax-type rapid expander (Palatinal split screw type S®, Forestadent Bernhard Förster GmbH, Pforzheim, Germany) cemented on first permanent molars. The activation protocol involved one quarter of turn (0.25 mm) in the morning and one quarter of turn in the evening for the first 2 weeks. Then, expansion proceeded at the rate of 0.25 mm/day until the upper molar palatal cusps were in contact with the lower molar buccal cusps. After the activation period (14-21 days), the appliance was used as a retainer for 6 months, then removed and replaced by an upper removable retention appliance. (Fig 1)

At RME removal (T1) orthodontic and ENT examinations were repeated.

The differences in the amount of nasopharynx obstruction between T0 and T1 were statistically analyzed using the Wilcoxon Signed Rank test, as the data were not found to be normally distributed. The Paired Samples 't' test was applied to assess the significance of T0-T1 differences in nasal resistance during inspiration and expiration, having preliminarily checked that the data met the requirements of normal distribution (Kolmogorov-Smirnov test) and homogeneity of group variances (Levene test). The statistical significance of the correlation between T0-T1 differences in the amount of nasopharynx obstruction and T0-T1 differences in airway resistance during expiration and inspiration was assessed with the Spearman's correlation coefficient. In all the analyses the level of significance was set at $\alpha=0.05$ and calculations were handled by SPSS 11.0 software (SPSS, Chicago, IL, USA).

RESULTS

The values of RM, the amount of expansion (expressed in activations) and the grading of nasal obstruction are summarized in table 1.

Nasoendoscopy performed at T0 showed that adenoid hypertrophy was the most common cause of airway obstruction (22 out of 30 patients). Inferior turbinates hypertrophy was the second most frequent cause (13 out of 30), followed by obstructive septal deviation (7 out of 30). No sleep apnea reported by parents probably due to lack of knowledge of this kind of pathologies. Medical history showed no general health problems were related to severe obesity.

The amount of nasopharynx obstruction decreased significantly after palatal expansion ($p<0.001$) (Table 2).

Total nasal inspiration and expiration resistance decreased significantly at T1 ($p<0.001$). The reduction ranged between 0.23 and 0.66 Pa/cm^3/s for inspiration and between 0.20 and 0.58 Pa/cm^3/s for expiration (Table 3).

Table 1. Description of the number of activation, grading of nasal obstruction and values of RM before and after treatment for each patient.

	Activations	Choanal grades		R Inspiration (Pa/cm3/s)		R expiration (Pa/cm3/s)	
		Pre	Post	PRE	POST	PRE	POST
Pt1	27	1	1	0.75	0.90	0.73	0.99
Pt2	22	3	1	1.81	0.22	1.81	0.23
Pt3	24	3	3	1.62	0.61	1.37	0.64
Pt4	14	2	1	0.38	0.22	0.28	0.23
Pt5	26	3	1	0.40	0.29	0.39	0.26
Pt6	14	1	1	0.33	1.59	0.48	1.06
Pt7	14	3	1	0.66	0.26	0.63	0.26
Pt8	22	1	1	0.57	0.23	0.50	0.28
Pt9	33	0	0	0.54	0.33	0.60	0.48
Pt10	24	0	0	0.77	0.50	0.86	0.55
Pt11	14	3	3	1.93	0.74	0.60	0.46
Pt12	21	0	0	0.81	0.32	0.87	0.30
Pt13	21	3	1	1.61	0.70	1.42	0.68
Pt14	23	3	3	1.75	0.95	1.59	0.98
Pt15	14	2	1	0.50	0.13	0.55	0.13
Pt16	21	3	2	0.58	0.58	0.64	0.64
Pt17	21	1	1	0.53	0.42	0.55	0.48
Pt18	26	1	1	1.27	0.56	0.93	0.51
Pt19	35	1	1	0.69	0.52	0.94	0.42
Pt20	30	0	0	0.51	0.64	0.51	1.15
Pt21	23	2	0	0.91	0.19	0.97	0.18
Pt22	14	3	2	0.56	0.28	0.62	0.29
Pt23	21	1	1	0.47	0.37	0.48	0.24
Pt24	25	3	2	0.82	0.30	0.91	0.28
Pt25	28	1	0	1.74	0.22	1.58	0.22
Pt26	27	3	3	0.86	0.28	0.96	0.30
Pt27	24	1	0	2.13	0.83	2.18	0.86
Pt28	14	1	1	0.22	0.22	0.23	0.23
Pt29	21	1	0	0.81	0.38	0.85	0.40
Pt30	28	3	1	0.46	0.13	0.47	0.11

Table 2. Descriptive statistics of the amount of nasopharynx obstruction, choanal grades, along with statistical significance as to before-after difference.

	N	Median	Interquartile range (25%-75%)	p value
T_0	30	1.5	1-3	<0.001
T_1	30	1	0-1	

Table 3. Descriptive statistics of nasal resistance during inspiration and expiration, measured in Pa/cm^3/s through rhinomanometry, along with statistical significance as to before-after differences.

Nasal resistance		Mean	Standard deviation	p value	95 percent confidence interval for difference of means
Inspiration	T_0	0.9	0.55	p<0.001	0.22 to 0.65
	T_1	0.46	0.31		
Expiration	T_0	0.85	0.47	p<0.001	0.22 to 0.65
	T_1	0.46	0.29		0.20 to 0.57

A statistically significant positive correlation existed between the T1-T0 differences in amount of nasopharynx obstruction and the T1-T0 differences in expiration nasal airway resistance (Spearman's's correlation coefficient rho = 0.38; p = 0.03). The positive correlation between the change in the amount of nasopharynx obstruction and the change in inspiration resistance was not statistically significant (Spearman's correlation coefficient rho = 0.38; p= 0.11).

DISCUSSION

There has been long-standing controversy over the efficacy of RME to relieve nasal obstruction and improve respiration.

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 [28,29,30] .

Previous studies with cephalometric measurements evaluated the modification of adenoidal tissue after palatal expansion and different findings were reported.

Picchi et al. [31] did not observe any significant change in the dimensions of the pharyngeal space after RME. Chiari et al [20] reported that maxillary expansion did not significantly affect the dimensions of adenoids and of the nasopharyngeal space as measured on lateral cephalograms.

Langer et al [32] observed increased nasopharyngeal area 30 months after RME. The authors inferred that such change could have been ascribed to craniofacial growth, rather than to RME treatment. Based on a cephalometric evaluation, Buccheri et al. [19] concluded that RME increased nasopharyngeal space in relation to the orthopedic effect in tissues that delimit maxilla, thus improving tongue position and increasing nasopharynx space.

Linder-Aronson and Leighton [33] and Vilella et al. [34] confirmed though cephalometry that at 4–5 years of age the adenoid tissue growth is markedly increased when compared to the nasopharynx, and at 10–11 years of age there is a decrease in tonsils size, which is continuous thereafter.

Cephalograms provide monodimensional sagittal views of adenoid tissue. Additionally, radiographic artifacts and magnification errors may affect cephalometric measurements.

Flexible nasopharingoscopy has demonstrated to be a safe, well tolerated procedure, allowing to directly observe adenoid tissue. Nasal fiberoptic endoscopy allows tridimensional evaluation of adenoid tissue and dynamic assessment of the nasopharyngeal space [35]. The same operator (LS) performed all rhinopharyngoscopic examinations were performed in the current investigation. A further assessment, by another calibrated investigator, could have strengthened the collected evidence. Nevertheless, even though fibroscopy is a non-invasive examination, some discomfort is involved in the procedure and the children disagreed to undergo a second examination.

In the present study, nasal fiberoptic examination showed that the amount of nasal obstruction reduced significantly after RME.

The reduction of the adenoid tissue that covered the choanal space after RME should not be interpreted as an absolute decrement in adenoid hypertrophy, but as an improvement in nasal obstruction. Almost all patients included in this study are located in CVS1 or CVS2 phase of cervical vertebrae maturation. The majority of them, did not show any change in the phase of cervical vertebrae maturation, as to X-ray control. Radiographic testing has been carried out about 6 months after the second ENT visit (T1). We, and other researchers before us, think it's a too short a time to affirm that the changes may be due to the growth.[36-38]

With regard to RM, this study shows that nasal resistance significantly decreases after RME both in inspiration and expiration. Such results are in line with the findings of Hershey et al. (1976) [10], Timms (1986) [39] ,Hartgerink *et al* [40] ,White *et al* [41], and Doruk *et al* [23].

Conversely, Giuca *et al* [42]., in a study of 17 children aged 9-12 years did not report any statistically significant difference in nasal resistance following RME. Warren et al. [11] and Hartgerink et al. [40] respectively observed that 30% and 35% of patients subjected to maxillary expansion did not show any significant change in nasal resistance.

Such discrepancy in the available literature data, may be attributed to the type of expander used for orthodontic correction, to patient variability, and to the starting size of adenoid tissue. In this study, all subjects were preliminarily evaluated by an otorhinolaryngologist using nasofibroscopy. The exam was performed in order to exclude from the study sample subjects with nasal pathologies such as infections, nasal polyps, mucosal hyperplasia, allergic rhinitis, that could have altered the individual response to palatal expansion.

Early palatal expansion has a great impact on skeletal changes and long- term correction of maxillary constriction [43]. Moreover, RME involves lower risk than adenoidectomy. It would be important to find a threshold value for nasal resistance or adenoid size to discriminate patients that could benefit from palatal expansion to such an extent that surgical procedures could be avoided.

Structural modifications of nasal airways following RME could therefore effectively contribute to changing the respiratory pattern from oral to nasal. Under such conditions, air passage through the nose would become more frequent and the exposition of adenoid tissue to pathogenic agents would consequently decrease.

The absence of control group in this study was due to ethical problem.

Although some studies use the CBCT for the evaluation of the upper airway,[44,45] for the purpose of the study and for ethical reasons we have not deemed appropriate and necessary, according to the recent literature, the use of CBCT.[46-48]

Finally, in disagreement with the cephalometric observations of Langer et al [32], in the present investigation a significant positive correlation emerged between reduction of the amount of nasopharynx obstruction and improvement in nasal resistance. Based on these findings, it can be speculated that nasal fossae, that are located at the entrance of nasal airflow, may be more important than nasopharynx to determine the features of nasal airflow.

CONCLUSION

The results of this study, confirm that RME has an influence on nasal resistance and the amount of nasopharynx obstruction.

Although palatal expansion cannot replace medical treatment (intranasal corticosteroids) or surgical procedures (adenoidectomy) when indicated, it brings the benefit to improve the patency of upper airways in patients with minor or moderate breathing problems when due to the presence of nasal obstruction.

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