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Comparison of nasal volume changes during rapid maxillary expansion using acoustic rhinometry and computed tomography

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SUMMARY The purpose of this study was to compare nasal volume changes using acoustic rhinometry (AR) and computed tomography (CT). The subjects were 10 children (6 girls and 4 boys, with an age range of 12–14 years) who required rapid maxillary expansion (RME) on the basis of their individual malocclusion. All patients were found to have normal nasal cavities following anterior rhinoscopic examination.

AR and CT were undertaken at the start of treatment (t_1) and 6 months after expansion (t_2). Volume changes due to expansion were evaluated using Wilcoxon's test, and the correlation between the two methods was assessed with correlation analyses.

Both methods demonstrated that nasal volume significantly increased following the use of RME ($P < 0.05$). Correlation analyses showed no difference in volume ($P > 0.05$) using either of the two methods.

Introduction

Tomes (1872) described the dentofacial changes associated with nasal airway impairment, which included enlarged adenoid facies. To date, many reports have been published concerning restricted nasal airway function and its subsequent effects on dentofacial development (Linder-Aronson 1979; Subtelny 1980; Bresolin *et al.*, 1983). It is commonly assumed that mouth breathing is often associated with deformities such as a retrognathic mandible, protruding maxillary anterior teeth, a high palatal vault, a constricted V-shaped maxillary arch, a flaccid and short upper lip, flaccid perioral musculature, and the appearance of an open mouth posture (Linder-Aronson and Aschan, 1963; O'Ryan *et al.*, 1982).

Various methods, such as intranasal (septum, turbinate, adenoids) and nasopharyngeal surgery, have been recommended to eliminate nasal blockage (Gluckman 1983; Sessions and Troost, 1993). The aim of these procedures is to increase airflow through the nose. In recent years, rapid maxillary expansion (RME) has been added to the list of recommended procedures to improve nasal airway respiration. Hartgerink *et al.* (1987) stated that RME eliminates the effects of nasal obstruction on facial form. It not only provides improvement in subjects with arch length discrepancies but also a decrease in nasal resistance following treatment. Hershey *et al.* (1976) found a significant decline in nasal resistance following RME. However, no quantifiable criteria exist for the determination of clinically significant nasal obstruction. It is easy to measure intermolar and intercanine width changes but this data cannot provide valid information in relation to airway dimension changes. Therefore, many methods have been applied to determine nasal airway dimensions.

Earlier methods for evaluating nasal airway volume have included lateral and postero-anterior cephalometric radiographs (Ricketts, 1968; Handelman and Osborne, 1976; Behfelt *et al.*, 1990). While these methods were useful in determining the obstruction of the nasal and pharyngeal area, they have proved inadequate for measuring nasal resistance, airflow, or nasal area.

Rhinomanometry is one of the most extensively used methods through which in recent years nasal respiration has been objectively characterized (Pallanch *et al.*, 1993). This technique involves recording pressure and flow simultaneously over a given time interval and allows the relationship between pressure, airflow, and time to be studied, and provides an objective assessment of the passage of air through the nose. It is possible from these data to derive a value of airway resistance to airflow. The disadvantage of the method, however, is that it requires the wearing of a mask while the measurements are being carried out.

Acoustic rhinometry (AR) was introduced as a useful tool for measuring nasal cavity dimensions (Hilberg *et al.*, 1989). AR provides an objective measurement of the relationship between the cross-sectional area and volume of the nasal cavity. The method is based on the analysis of the sound reflection from the nasal cavity, taking into account the properties of the incident sound submitted to the nasal cavity along with associated reflected sound waves (Figure 1). It is a quick, painless, non-invasive, and reliable method that can be performed easily with minimal patient co-operation (Cakmak *et al.*, 2001). Kim *et al.* (1998) examined the changes in nasal cavity after adenoidectomy and tonsillectomy with AR. Wriedt *et al.* (2001) investigated changes after surgically assisted RME on nasal volume.

AR has been used to evaluate nasal resistance in patients, 8 months after RME (Doruk *et al.*, 2004).

Montgomery *et al.* (1979) initially studied the nasal airways in human cadavers using computed tomography (CT). All the facial tissues and related anatomic spaces, including the nasal airways, can be assessed accurately in three dimensions using CT. CT has become popular in diagnosing deformities, tumours, and structures of the body (Haponik *et al.*, 1983; Ericson and Kurol, 1988). Nevertheless, not only is it an expensive method but also can be difficult to undertake in children due to a lack of co-operation.

The aims of this study were to evaluate nasal volume changes using CT and AR and to compare the two methods.

Subjects and methods

Ten patients (six girls and four boys) with an age range of 12–14 years were studied. The selection criteria were maxillary transverse narrowness with bilateral crossbite, with no previous history of nasal disease. The study protocol was approved by the local ethics committee and both the patient and parents were informed about the general aims of the study.

A modified bonded RME appliance (Figure 2), with full occlusal coverage, was selected to provide control of the vertical dimension during maxillary expansion (Alpern and Yurosko, 1987). A hyrax screw (GAC International, Islandia, New York, USA) was placed between the first premolars as close as possible to the palate. Glass ionomer cement (Ketac-Cem; Espe Dental Ag, Seefeld, Germany) was used for cementation. Small relief holes were placed in the appliance to facilitate cement flow and aid full seating. All patients were instructed to activate the screw twice a day for the first week (0.5 mm) and then once a day (0.25 mm) until the posterior crossbite was eliminated.

Method of AR recording

All AR measurements were carried out at room temperature (20°C). The patients were allowed to rest for 30 minutes before the recording commenced and the device was calibrated. After calibration, the nosepiece was placed in the nostril with the patient seated. Nasal volume was measured (four times for each nostril) before the application of any decongestant. Following this, nasal decongestant spray (Iliadin; Merck KgaA, Darmstad, Germany; 0.5 mg oxymetazoline hydrocloride/ml) was applied to each nostril and the process of measurement began after a time delay of 10 minutes, which allowed time for the decongestant to take effect. The average of the four values recorded was used to determine the nasal volume in relation to each nostril. Nasal volume was then determined for both left and right sides and they were summed to obtain the total nasal volume. The nasal volume was measured with AR before treatment (t_1) and 6 months after achieving satisfactory expansion (t_2).

CT procedure

All patients underwent a CT examination following AR measurement. For coronal scanning, the patient was placed prone on the table with the chin hyper-extended. The scanner gantry was angled perpendicular to the hard plate. The appearance correlates with a wide-window setting (range 3000–4000 Hounsfield unit) and coronal with the true measurement of the air space, and thus these were used. Scanning was performed as contiguous 4 mm-thick and 4 mm interval images from the base of the nostrils to the posterior nasal spine. The field of view mean value was

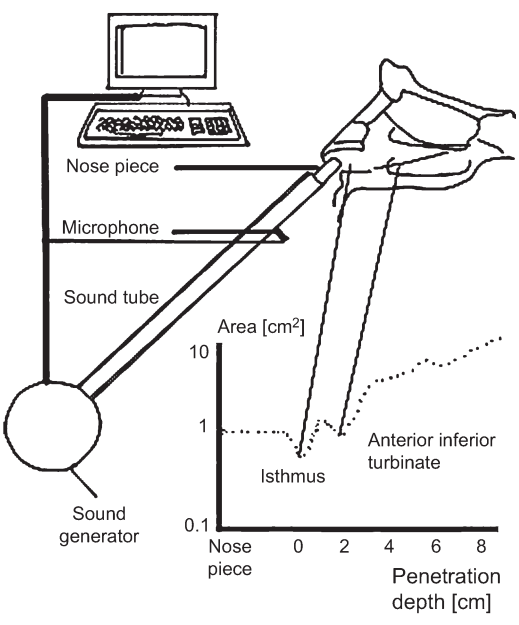

Figure 1 Diagram of the acoustic rhinometry device.

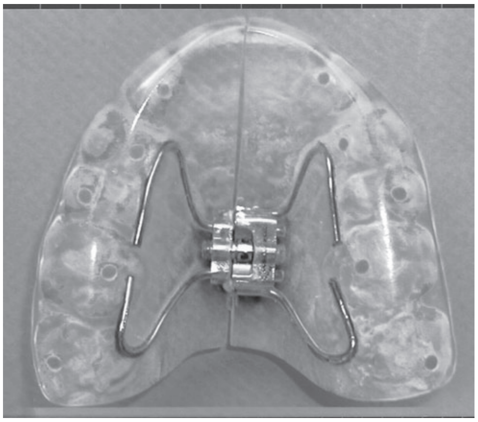

Figure 2 Modified bonded rapid maxillary expansion appliance.

6.7 ± 0.3 cm. Contiguous scans were essential to avoid loss of information. Nasal air volume was then measured from three-dimensionally reconstructed images on an external computer.

All CT and AR results were evaluated by one author (UY), a radiologist, and an experienced otolaryngologist.

Method of error and statistical analysis

The AR device took a minimum of 10 successive mean rhinograms automatically for each measurement. All measurements were repeated four times for each patient and, in an attempt to reduce any possible errors, the mean value was used.

Volume changes due to expansion with the two methods were evaluated using a Wilcoxon matched signed ranks test. Correlation analysis was used to determine the correlation between the two methods.

Results

The mean duration of active expansion and retention was 20.7 ± 4.6 days and 6 ± 2.2 months, respectively. The mean intercanine expansion was 5.02 ± 1.52 mm and the mean intermolar expansion 5.97 ± 2.40 mm at t_2. There was an increase in nasal volume between t_1 and t_2 for both measurements (Figure 3). This increase was statistically significant for both methods ($P < 0.05$; Table 1). The differences between the two methods were not significant [AR(t_1) − CT(t_1)r = 0.32, AR(t_2) − CT(t_2)r = 0.48)].

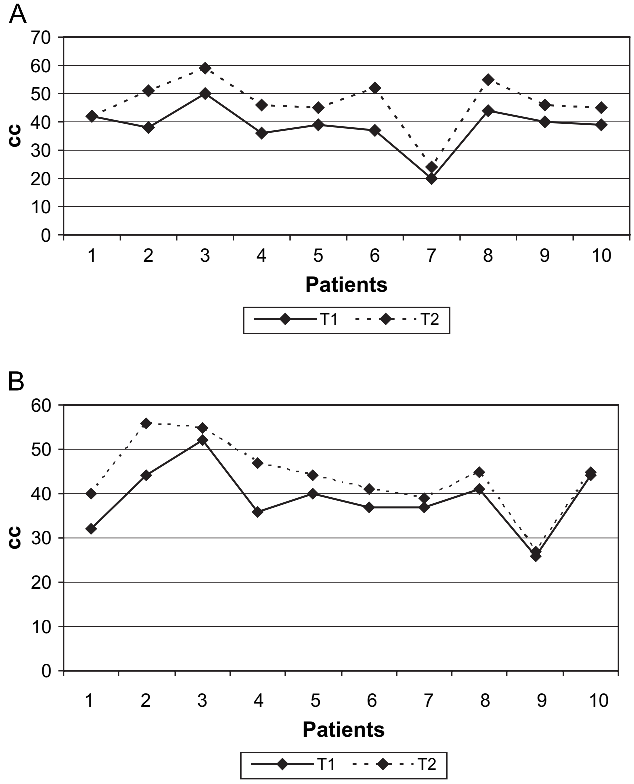

Figure 3 Graphs showing the changes of nasal volume following expansion in all patients using acoustic rhinometry (a) and computed tomography (b).

Table 1 Mean and standard deviation (SD) in cubic centimetres of nasal volume measurements before treatment (t_1) and at the end of the retention period (t_2).

	t_1, mean ± SD	t_2, mean ± SD	Significance
Computed tomography, n = 10	38.9 ± 7.14	43.9 ± 8.26	*
Acoustic rhinometry, n = 10	38.5 ± 7.46	46.5 ± 9.48	*

*$P < 0.05$.

Discussion

Expansion of the midpalatal suture has become an accepted procedure for the treatment of maxillary constriction and associated arch length discrepancies. The concept of maxillary expansion has been extended to the nasal cavity as previous studies have suggested that with expansion, an increase in nasal width and volume are obtained (Wertz and Dreskin, 1977). The traditional explanation for the influence of RME on nasal volume is based on the separation of the lateral walls of the nasal cavity, which occurs concurrently during dental arch expansion. The increase in the distance between the lateral walls of the nasal cavity increases nasal volume and enlarges the cross-sectional area of the nasal passage, facilitating breathing. Doruk *et al.* (2004) found that an increase in intercanine width results in a significant decrease in nasal resistance due to the direct effect exerted on the nasal valve area. The nasal valve is the region of the nasal airway extending from the caudal end of the upper lateral cartilage to the anterior aspect of inferior turbinate (Santiago-Diez de Bonilla *et al.*, 1986). With the widening of nasal valve, RME indirectly causes a widening at the anterior nares, which contributes to reductions in nasal resistance (Hartgerink *et al.*, 1987; Warren *et al.*, 1987). Therefore, Wertz (1968) recommended using RME only when an obstruction was present in the antero-inferior aspect of the nose, the area most favourably affected by maxillary expansion.

Lateral cephalometric radiographs have been used for examining dentofacial structures, nasal airway, and related areas. Although there is no clear connection between the oro- and hypo-pharyngeal areas on lateral cephalometric radiographs, it is claimed that there is a direct relationship between the two-dimensional cephalometric film measurement of the tongue, palate, and nasopharyngeal areas (Sorensen *et al.*, 1980; Grayson *et al.*, 1988; Thüer *et al.*, 1989).

CT is currently the modality of choice in the evaluation of the paranasal sinuses and adjacent structures (Zinreich and Kenneth, 1993). However, most orthodontists do not advise routine CT because patients are exposed to high doses of radiation; it is time consuming, expensive, and not readily available.

For decades, rhinologists have been trying to find an objective means of assessing the nasal airway that can be applied to a broad spectrum of patients. Hilberg *et al.* (1989) introduced AR as a useful tool for measuring the dimensions of the nasal cavity. This is a quick, painless, non-invasive, and reliable method that can be performed easily and requires minimal patient co-operation. AR is suggested for characterizing the geometry of the nasal cavity, quantifying the dimensions of nasal obstructions and assessing the results of surgery and response to medical treatment. Computer technology has made measurement analysis easier but the method remains to be more widely accepted in clinical practice.

While a number of methods have been used to evaluate the effects of RME, most of these originate from departments of otolaryngology (Ceylan *et al.*, 1996; Doruk *et al.*, 2004), where AR has become an accepted method (Wriedt *et al.*, 2001; Bicakci *et al.*, 2005). The aim of this investigation was to determine the accuracy and reliability of AR by comparing it with CT.

In the current study, both measurement methods demonstrated an increase in nasal volume after RME, of AR 11.16 and CT 13.28 per cent. These findings show that the results were similar and that both techniques were well correlated. Cankurtaran *et al.* (2003) undertook experimental studies to test the reliability of AR in determining nasal valve area. Their results showed the technique to be reliable in quantifying changes in the anterior portion of the nasal cavity but not in relation to the cross-sectional area of the posterior nasal cavity.

In another study using magnetic resonance scanning, a good correlation with AR was found in relation to the anterior 6 cm of the nasal cavity (Hilberg, 2002). For the posterior nasal cavity and epipharynx, differences were found mainly due to sound loss in the paranasal sinuses.

In the present study, the distance from the base of nostrils to the posterior nasal spine was examined, which is approximately 6.7 cm in length. The results of AR showed good correlation with CT.

Conclusion

The complex structure of the nasal cavity makes evaluation of the nasal airway difficult. Acoustic reflection provides a non-invasive, easy, and valid method of measuring nasal volume.

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