European Journal of Orthodontics 32 (2010) 716–720
doi:10.1093/ejo/cjp164
Advance Access Publication 19 April 2010

Effects of rapid maxillary expansion with a memory palatal split screw on the morphology of the maxillary dental arch and nasal airway resistance

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SUMMARY The purpose of this study was to investigate the effects of rapid maxillary expansion (RME) with a memory palatal split screw on the morphology of the maxillary dental arch and nasal airway resistance (NAR). The material consisted of the rhinomanometric records and study models of 15 patients (8 females and 7 males) with mean age of 12.89 ± 1.20 years. Data were collected before expansion (T1), immediately after expansion (T2), and after a retention period of 6 months (T3). Maxillary expansion was completed within 8 days in all subjects. The data were analysed by analysis of variance. The least significant difference test was also used to determine between which periods the changes in the measurements were significant.

Statistical analyses showed that NAR decreased ($P < 0.01$) and intermolar and interpremolar distances increased ($P < 0.001$) significantly at all observation periods, except between T2 and T3.

RME using a memory palatal split screw is effective for improvement of nasal respiration via a widening effect on the nasal cavity.

Introduction

Maxillary constriction or hypoplasia is one of the most common skeletal problems seen in the craniofacial region (McNamara, 2000). Laptook (1981) defined maxillary constriction with a high palatal vault as a 'skeletal developmental syndrome'. According to that author, this syndrome evidences certain rhinologic as well as dental characteristics, such as decreased nasal permeability resulting from nasal stenosis, elevation of the nasal floor, mouth breathing, a bilateral dental maxillary crossbite along with a high palatal vault, and enlargement of nasal turbinates causing a decrease in nasal airway size.

Mouth-breathing individuals have been classically described as possessing a narrow and V-shaped maxillary arch, a high palatal vault, a long face, and other malocclusions (Lessa *et al.*, 2005).

Maxillary arch constriction or transverse maxillary deficiency is commonly treated by expanding the mid-palatal suture. Rapid maxillary expansion (RME) introduced by Angell (1860) was reintroduced and popularized during the 1960s by Haas (1961, 1965). RME is a distraction procedure that splits the mid-palatal suture and separates the two maxillary halves in a short period of time. It is often used to widen the maxilla in young patients with a unilateral or bilateral crossbite, concomitant with a constricted and high palatal vault (Bishara and Staley, 1987).

Orthopaedic expansion of the maxilla concomitantly results in a widening of the nose. Because the maxillary bones form half of the anatomic structure of the nasal cavity, it has been hypothesized that mid-palatal disjunction would affect the anatomy and physiology of the nasal cavity (Hershey *et al.*, 1976; Warren *et al.*, 1987). Literature reviews suggest that this orthopaedic procedure may result in dento-skeletal effects as well as some advantageous rhinological effects (Neeley *et al.*, 2007; Kilic and Oktay, 2008).

The nasal valves are the minimal cross-sectional areas of the nose and, therefore, the site of greatest resistance to nasal airflow (Yu *et al.*, 2008). RME promotes the separation of the maxillary bones in a pyramidal shape, i.e. maximum expansion occurs at the level of the incisors just below the nasal valves (Wertz, 1970). Numerous studies have investigated the possible relationships between conventional RME procedures and changes in nasal breathing and nasal airflow. It has been clearly shown that nasal airway dimensions and, concomitantly, nasal volume increases (Compadretti *et al.*, 2006b; Doruk *et al.*, 2007; Cappellette *et al.*, 2008) and nasal airway resistance (NAR) decreases (Hershey *et al.*,1976; Timms, 1986; Hartgerink *et al.*, 1987; Doruk *et al.*, 2004; Compadretti *et al.*, 2006a; Enoki *et al.*, 2006) after RME.

Conventional RME appliances expand the maxillary halves with heavy intermittent forces up to 10 kg (22.5 pounds; Isaacson and Ingram, 1964). Wichelhaus *et al.* (2004) introduced a new 'memory palatal split screw' for RME. According to those authors, this new screw produces a rapid, constant, and low physiological force that causes efficient expansion. It has been suggested that expansion of the maxilla with low physiological forces followed by rapid separation of the mid-palatal suture would stimulate the adaptation processes in the nasomaxillary structures and result in less relapse potential in the retention period (Mew, 1977; Iseri *et al.*, 1998; Iseri and Özsoy, 2004)

However, the effects of this new expansion screw on the nasomaxillary complex and possible rhinolologic outcomes have not yet been investigated. This study aimed to determine changes in NAR and the maxillary dental arch caused by RME with the memory palatal split screw.

Materials and methods

Informed consent was obtained from the parents of all subjects at beginning of the study. The research was approved by the local ethics committee (2009/019).

The research consisted of the rhinomanometric records and study models of 15 patients (8 females and 7 males) who had undergone RME with the memory palatal split screw (Memory Expander Type 'N'; Forestadent, Pforzheim, Germany) at the Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey. All patients had a severe maxillary width deficiency, a bilateral crossbite, and a deep palatal vault (Figure 1a). The age range of the patients was 11–15 years (mean 12.89 ± 1.20 years).

The memory palatal split screw was welded to the first premolar and molar bands and then the RME appliance cemented to the teeth. The parents of the patients were instructed to activate the expansion screw two-quarter turns in the morning, at midday, and in the evening (six-quarter turns a day). An occlusal radiograph of each patient was obtained at the end of 12 turns to ensure mid-palatal suture opening. The memory screw was activated until the occlusal aspect of the maxillary lingual cusp of the upper first molars contacted the occlusal aspect of the facial cusp of the mandibular first molars (Figure 1b and 1c).

Study models and rhinomanometric records were obtained at three different time points: before RME (T1), at the end of expansion (T2; mean = 8 days), and at the end of retention, a period of approximately 6 months (T3).

Maxillary expansion was evaluated at T1, T2, and T3 by measuring the changes in interpremolar and intermolar distances on the study models. All measurements were carried out by one author (KH) using high-precision digital callipers with an accuracy of 0.01 mm (Digimatic Calliper CD-6 inCX; Mitutoyo American, Plymouth Michigan, USA). The coefficients of reliability regarding these measurements were also calculated (0.996 for intermolar distance and 0.994 for interperemolar distance).

Rhinomanometric records were obtained by an audiologist according to the proposals of Clement and Gordts (2005). These records were taken at the same room temperature (20°C) and at a constant humidity. After calibration of the device (Rhino 4000; Homoth Medizinelektronik, Hamburg, Germany) according to the manufacturer's instructions, the

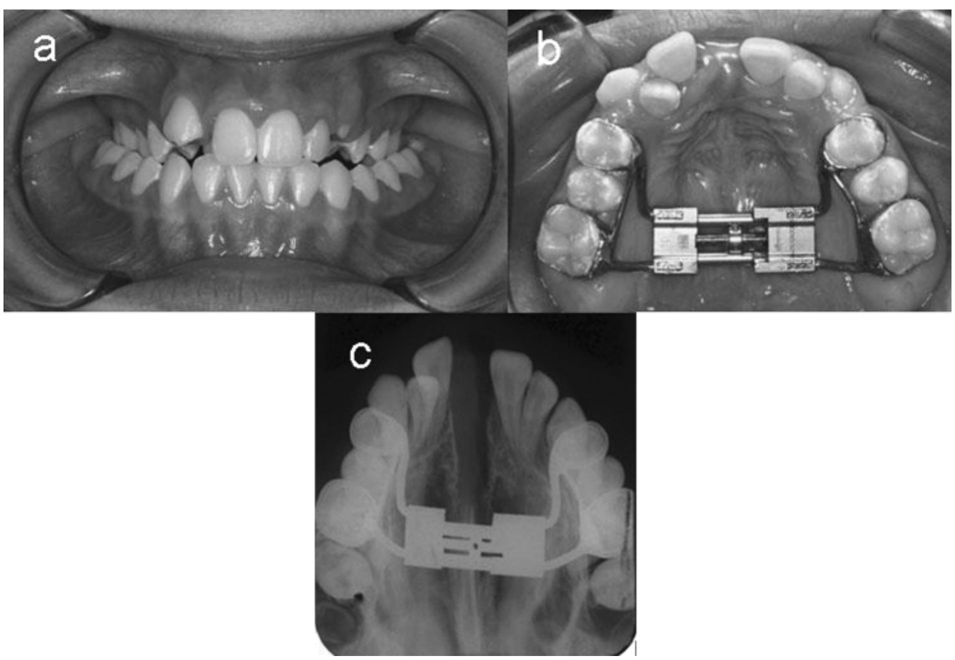

Figure 1 A female patient aged 13 years. (a) Intra-oral view before rapid maxillary expansion. (b) Memory palatal split screw on the expanded maxillary arch. (c) Occlusal radiographic view of the hard palate after expansion.

measurements were obtained in a sitting position with a relaxed body posture, after an adaptation period of 20–30 minutes. After a further adaptation period of 20–30 minutes, decongestant nasal spray (Iliadin, Santa Farma, Turkey) was applied to the nostrils in order to eliminate mucosal variations attributable to the nasal cycle. All measurements were repeated four times for each patient, in an attempt to reduce any possible errors, and the mean value was computed.

Statistical analysis

Descriptive statistics of NAR and intermolar and interpremolar widths were calculated for each measurement period. The data were analysed by analysis of variance (ANOVA). The least significant difference (LSD) test was also used to determine between which periods the changes in the measurements were significant.

Results

Descriptive statistics regarding NAR and maxillary arch widths are shown in Table 1. The increase in intermolar and interpremolar distances was 8.5 and 8.2 mm, respectively.

The results of ANOVA regarding NAR and maxillary arch widths are summarized in Table 2. ANOVA showed that statistically significant changes occurred between the observation periods. The results of the LSD test are presented in Table 3. As can be seen, NAR decreased significantly in both nostrils with and without application of the decongestant at all observation periods, except between T2 and T3, while intermolar and interpremolar distances increased significantly ($P < 0.001$) at all observation periods, except between T2 and T3.

Discussion

Maxillary transverse deficiency and a posterior crossbite is a common clinically encountered malocclusion (Ingervall, 1974; Thilander *et al.* 2001). According to Hershey *et al.* (1976), patients requiring maxillary expansion due to a constricted palate and posterior crossbite have a nasal resistance which tends to produce a mouth-breathing pattern. The associations between maxillary constriction concomitant with a posterior crossbite and mouth breathing were shown in a recent literature review (Kilic and Oktay 2008).

In this study, inspiratory nasal volume was used to calculate NAR. Inspiratory nasal resistance is a more reliable indicator of true nasal airway function than expiratory nasal resistance (Guenthner *et al.*, 1984). McCaffrey and Kern (1979) noted, in a study of 1000 subjects with rhinologic complaints, that inspiratory NAR correlated well with the side-effects and severity of nasal obstructive symptoms. In order to reduce the method error, each rhinomanometric measurement was repeated four times and the mean value was used for statistical evaluation (Doruk *et al.*, 2007)

Different types of RME appliances have been developed. The most widely used (Haas and Hyrax) produce very high and intermittent forces since the expansion screw has a rigid structure. The effects of conventional RME appliances on nasal volume, cross-sectional area, and NAR have been evaluated in several studies (Hershey *et al.*, 1976; Warren *et al.*, 1987; Doruk *et al.*, 2004, 2007; Oliveira De Felippe *et al.*, 2008). Nonetheless, the present study was designed to evaluate the effects of a new expansion screw (memory palatal split screw) that included a super elastic NiTi spring (Wichelhaus *et al.*, 2004) on NAR and the maxillary dental arches. The main difference between the present and previous similar studies is the use of a new RME screw and its possible effects on the nasomaxillary complex. It was previously

Table 1 Mean, standard deviation, minimum, and maximum values of the parameters at three time points (T1, before expansion; T2, immediately after expansion; T3, after retention of 6 months) ($N = 15$). (NAR, Pascals/cc/sec × 10^3).

	Time	Mean	Standard deviation	Minimum	Maximum
Right nostril	T1	348.00	36.00	300.00	430.00
non-decongestant	T2	322.00	22.50	300.00	390.00
	T3	321.00	20.00	300.00	360.00
Left nostril	T1	363.00	41.00	310.00	440.00
non-decongestant	T2	319.00	26.00	270.00	370.00
	T3	326.00	21.00	300.00	360.00
Right nostril	T1	335.00	30.00	310.00	390.00
decongestant	T2	307.00	11.00	300.00	330.00
	T3	317.00	26.00	290.00	390.00
Left nostril	T1	336.00	29.00	300.00	390.00
decongestant	T2	316.00	23.00	270.00	370.00
	T3	316.00	15.00	300.00	350.00
Intermolar	T1	40.83	2.56	38.33	48.15
distance (mm)	T2	49.38	3.50	44.16	58.91
	T3	50.20	3.24	45.85	58.13
Interpremolar	T1	29.42	3.34	23.57	37.72
distance (mm)	T2	37.56	4.14	29.05	47.07
	T3	38.09	3.78	30.24	47.13

Table 2 Analysis of variance of nasal resistance and maxillary width measurements.

	Sum of squares	Degree of freedom	Mean square	*F* value	Significance
Right nostril non-decongestant	0.007	2	0.004	4.860	0.013
Left nostril non-decongestant	0.017	2	0.008	9.060	0.001
Right nostril decongestant	0.007	2	0.004	6.510	0.003
Left nostril decongestant	0.004	2	0.002	3.604	0.036
Interpremolar distance	708.219	2	354.110	24.961	0.000
Intermolar distance	807.072	2	403.536	41.285	0.000

Table 3 Results of least significant difference test explaining the significance of analysis of variance.

	Pre-expansion (T1)	Post-expansion (T2)	Post-retention (T3)	Comparison of the means		
	Mean	Mean	Mean	T1–T2	T1–T3	T2–T3
Right nostril non-decongestant	348.00	322.00	321.00	*	**	NS
Left nostril non-decongestant	363.00	319.00	326.00	***	**	NS
Right nostril decongestant	335.00	307.00	317.00	**	**	NS
Left nostril decongestant	336.00	316.00	316.00	*	*	NS
Intermolar distance	40.83	49.38	50.20	***	***	NS
Interpremolar distance	29.42	37.56	38.09	***	***	NS

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; NS, not significant.

shown by Wichelhaus *et al.* (2004) that the memory palatal split screw generates sufficient force that produces mid-palatal sutural opening and orthopaedic separation of the maxillary halves. Wichelhaus *et al.* (2004) showed that the level of the force produced by this screw is sufficient to produce skeletal expansion; however, the question as to whether the skeletal separation reached the upper structures of the nasomaxillary complex and whether separation resulted in a reduction of NAR remained unanswered.

The findings of the present research show that the mean NAR significantly decreased after RME and the results were stable during the retention period. In other words, RME carried out using the memory palatal split screw resulted in stable NAR reduction. This means that skeletal expansion induced by the low forces of this screw affected the nasomaxillary complex. According to Wichelhaus *et al.* (2004), this screw produces rapid and constant physiological expansion, and thus, these forces result in more effective maxillary expansion in a shorter duration. A number of studies have stressed that maxillary expansion induced by low physiological forces followed by rapid separation of the mid-palatal suture stimulates adaptation of the processes of the nasomaxillary structures and results in less relapse potential in the retention period (Mew, 1977; Iseri *et al.*, 1998; Iseri and Özsoy, 2004). Isaacson and Ingram (1964) hypothesized that the total expansion might be physiologically stable in a shorter net treatment time with expansion procedures carried out at lower forces. In the present study, adequate maxillary expansion was accomplished in 8 days with relatively constant lower forces than those produced by conventional expanders. Isaacson and Ingram (1964) measured the forces caused by RME and found that three-quarter turns of the screw produced higher forces ranging from 6 to 10 pounds. They also found an expansion force up to 22.5 pounds (approximately 10 kg) in a female patient aged 15.5 years. However, the memory screw generates a relatively continuous force ranging from 1225 to 1425 *g* (Wichelhaus *et al.*, 2004).

The findings of the present study show that this new expansion screw produces sufficient skeletal expansion, which affects the nasomaxillary complex and results in a significant reduction in NAR, equal to the effects of conventional RME expanders (Doruk *et al.*, 2004; Compadretti *et al.*, 2006a; Enoki *et al.*, 2006). RME appliances expand the narrowed maxillary arches in a transverse direction by rapid separation of the mid-palatal suture and concomitantly splitting of the maxillary halves (Haas, 1965; Wertz, 1970).

The maxilla is the largest bone of the face and forms most of the lateral walls of the nasal cavity (Fingeroth 1991). Application of RME results in considerable changes in the nasomaxillary complex (Haas, 1961, 1965; Wertz, 1970). Traditionally, the possible influence of basal maxillary expansion on nasal volume and airflow was based on concomitant transverse expansion of nasal cavity (Haas, 1961; Wertz, 1968; Iseri *et al.*, 1998). Widening of the nasal cavity increases nasal volume and the cross-sectional area of the nasal passage (Hershey *et al.*, 1976; Warren *et al.*, 1987; Doruk *et al.*, 2004, 2007; Kilic and Oktay, 2008; Oliveira De Felippe *et al.*, 2008) facilitating breathing.

Numerous studies have investigated the changes in nasal airflow caused by RME. White *et al.* (1989), Timms (1986), Hartgerink *et al.* (1987), Hershey *et al.* (1976), and Doruk *et al.* (2004) clearly showed that NAR significantly decreased after RME. These findings were also supported by clinical studies of the effects of RME on nasal volume (Babacan *et al.*, 2006; Compadretti *et al.*, 2006b; Doruk *et al.*, 2007) and cross-sectional area (Iseri *et al.*, 1998; Bicakci *et al.*, 2005).

Enoki *et al.* (2006), in an evaluation of 29 children with oral and/or mixed breathing who underwent RME therapy, showed a statically significant reduction in NAR, although no significant changes in the minimal cross-sectional area at the level of the valve and inferior nasal turbinate. Compadretti *et al.* (2006a) evaluated geometric changes of the nose after RME and assessed the possible effects of this procedure on nasal airway size by means of acoustic rhinometry. Those authors observed a satisfactory transverse expansion of the maxilla and a significant increase in nasal volume. Oliveira De Felippe *et al.* (2008) conducted a study to assess the short- and long-term effects of RME on the morphology of the maxillary dental arch, nasal cavity dimensions, and NAR by means of three-dimensional imaging and acoustic rhinometry. They found that RME produced an increase in palatal area, nasal volume, and intermolar distance and a reduction of NAR with improvement in nasal respiration after the active phase of RME in 61.3 per cent of 38 subjects.

Rhinomanometric results should be interpreted with care. While special attention was given to the NAR measurements and the mean values used in the statistical analyses were computed from four repeated records, the results obtained in the present study might have been influenced by small growth changes, although any growth that occurred during a period of 6 months would be negligible.

Conclusions

RME carried out with the memory palatal split screw produced significant expansion in interpremolar and intermolar distances and considerable effects on NAR. Further investigations with a larger sample size should be performed to confirm the results of the present study.

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