Original Article

Changes in Head Posture after Rapid Maxillary Expansion in Mouth-Breathing Girls: A Controlled Study

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Abstract: The influence of respiratory function on craniofacial development and head posture has been demonstrated previously. This study evaluated the effect of rapid maxillary expansion (RME) on nasopharyngeal airway adequacy, head posture, and facial morphology in children with nasal obstruction. Fifty-five girls (8–15 years of age) who needed maxillary expansion, showed reduced nasopharyngeal airway adequacy (pm-Ad 2), and were subjectively assessed as mouth breathers were allocated randomly into 2 groups. The 23 subjects in the first group were treated with RME, and the 22 subjects in the other group were followed about 8 months before beginning therapy and became untreated controls. Dental casts and lateral skull radiographs exposed in natural head position were obtained at the first visit and 6 months later for all subjects. In the girls under active treatment there was a statistically significant increase of pm-Ad 2 ($P < .0001$), a significant increase of the cervical lordosis angle ($P < .0001$), a flexion of the head ($P < .0001$), and a decrease in the craniocervical angulation ($P < .0001$) (paired *t*-tests). No significant changes were seen in the control group. The correlation coefficients indicated a mild correlation between pm-Ad 2 distance and craniocervical angulation (SN/OPT angle) ($r = 0.61$ at $P < .001$). RME is capable of increasing nasopharyngeal airway adequacy in girls, and this leads to a decrease in craniocervical angulations. The clinical importance of these results is yet to be clarified. (*Angle Orthod* 2005;75:171–176.)

Key Words: Head posture, Respiratory function, Maxillary expansion

INTRODUCTION

Research in the field of craniofacial growth and development has shown that respiratory airway function influences facial morphology and head posture.[1–13] Ricketts[3] hypothesized a relationship between head posture and respiratory functional demands when he reported that extension of the head was a functional response to facilitate oral breathing in order to compensate for nasal obstruction.

Solow and coworkers[6,8] confirmed this hypothesis and provided evidence involving neuromuscular feedback and passive stretching of the soft-tissue layer covering the face and neck.[14] According to this theory, children with airway obstruction would be expected to show an increased craniocervical angulation.[14] Later, this was confirmed by Solow et al[8] in a sample of 24 nonpathologic, 7- to 9-year-old subjects. Later, it was also observed that total nasal obstruction caused an immediate head extension,[15] influenced postural electromyographic activity in the neck and masticatory muscles,[16] and could play a role in snoring and obstructive sleep apnea.[17]

On the basis of this evidence, several researchers observed significant changes in head posture and craniocervical angulation after therapy aimed at improving the nasal respiratory function in longitudinal studies. For example, Solow and Greve[6] and Woodside and Linder-Aronson[18] independently observed a reduction of about 2° in craniocervical angulation two months after adenoidectomy in pathologic children. In addition, the differences in head posture between pathologic and control children disappeared.[18]

In 1983, Wenzel et al[19] in a longitudinal, double-blind, controlled study showed that a pharmacological treatment with budesonide improved respiratory function and caused a decreased craniocervical angulation in addition to decreased nasal resistance.

Even today, however, information is lacking on the effects of rapid maxillary expansion (RME) on head posture and craniocervical angulations. This is true despite the fact

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TABLE 1. Changes With Treatment in the Study Group. Cephalometric and Dental Cast Measurements for 23 Cases Before Treatment and at the End of Rapid Palatal Expansion

	Pretreatment				Posttreatment				Change with Treatment				
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	*P* value
pm-Ad 2	10.5	3.4	6.4	16.8	15.8	3.5	9.8	20.2	5.3	1.9	−0.5	8.2	.0001*
Postural variables													
CVT/EVT (°)	9.77	4.15	3.5	16	12.96	4.30	5.5	18	3.19	4.20	3.5	3.78	.001*
Cervical inclination													
OPT/Ver (°)	2.08	3.68	−6	6	5.75	3.82	−6	6	3.67	3.72	3.02	3.84	.001*
CVT/Ver (°)	2.48	4.10	−6	11.50	2.96	4.71	−5	10	0.48	1.49	−0.8	0.93	.448
EVT/Ver (°)	−6.85	5.73	−18.5	3	−7.5	6.9	−18.5	3	0.65	1.30	0.10	0.02	.452
Craniofacial inclination													
SN/Ver (°)	90.75	12.95	73	110	85.5	14.67	73	113	−5.25	−9.5	10.5	7.2	.0001*
PP/Ver (°)	81.21	11.11	62	99	86.25	9.65	72	100	−5.04	3.30	4.2	7.8	.0001*
MP/Ver (°)	60.80	7.89	45	75	56.40	8.32	43	75	−4.40	1.15	−9.9	4.9	.0001*
Craniocervical inclination													
SN/OPT (°)	82.5	4.96	75	93	77.4	5.09	72	92	−5.1	2.40	−9.5	3.2	.0001*
SN/CVT (°)	86.71	5.30	78	99	86.20	4.96	72	93	−0.51	0.9	−8.5	3.5	.573
PP/OPT (°)	75.46	4.50	69	83	71.10	4.40	72	85	−4.36	2.15	−8.5	4	.0001*
PP/CVT (°)	78.75	4.74	71	88	79.17	5.62	71	88	0.42	1.15	0.5	1.10	.2725
MP/OPT (°)	56.37	4.47	49	66	51.25	5.10	44	66	−5.12	2.50	1.2	9.5	.0001*
MP/CVT (°)	59.21	4.14	53	68	59.5	4.62	53	67	0.29	1.05	−0.90	1.80	.0865

* Significant values ($P < 0.05$).

that the typical malocclusion associated with respiratory obstruction is characterized by a reduced transverse palatal dimension[20] and RME is the primary device used in the orthodontic treatment of insufficient transverse dimension of the maxillary base.

The treatment outcomes associated with RME have previously been investigated and have focused on the changes in facial morphology,[21] respiratory function,[22–25] and nocturnal enuresis in children who are subject to psychosocial stress conditions,[26] without any consideration of head posture and craniocervical angulation.

For these reasons the aims of this study were to evaluate RME treatment outcomes and to compare the results with those of untreated controls, with special emphasis on changes in head posture and craniocervical angulation in a group of Caucasian girls. All the girls needed maxillary expansion, radiographically showed an obstructed nasopharyngeal airway, and had been subjectively assessed as mouth breathers. If a statistically significant difference were observed between the study and the control groups, the clinician would better understand the mechanism that is the basis of the complex relationships among respiratory function, head posture, and facial morphology.

MATERIALS AND METHODS

The sample

The sample included 55 girls (mean age 8.1 ± 2.0 years [SD]; range 8–15), consecutively admitted for orthodontic treatment in the Department of Orthodontics and Gnathology, University of Chieti, who needed maxillary expansion. The criteria for selection were based on sex, European ethnic origin, confirmed date of birth, cephalometrically demonstrated reduced nasopharyngeal airway adequacy, and mouth breathing according to parental information and subjective impression. Exclusion criteria were nasal allergic conditions or airway obstructions due to adenoids and previous orthodontic treatment. The mean pretreatment skeletal class value (ANB angle) was 3.8° (±1.52) (Tables 1 and 2).

The patients were divided randomly into 2 groups. Subjects in the first group were scheduled to begin treatment soon after the first visit (study group, 23 children). About 8 months after the first visit the second group began therapy (control group, 22 children). Subjects in the control group did not undergo any type of treatment (orthodontic or pharmacological therapy) during the period of observation. In the study group there were 15 patients with anterior or posterior crossbites. In the control group there were 13 patients with anterior or posterior crossbites.

The expansion regimen was 4 turns on the first day followed by 2 turns per day until the required expansion was achieved (1 turn = 0.2 mm). After the expansion the appliance (REP®, Dentaurum Italia sr l, Funo, Bologna, Italy) was left in place for a mean time of 4.7 ± 0.8 months (range 3.6–5.9 months). The expansion and retention regimens were decided by 1 operator, based on clinician preference and the patients' individual malocclusions.

The study was approved by the Ethics Committee of the

TABLE 2. Changes With Treatment in the Control Group. Cephalometric and Dental Cast Measurements for 22 Cases at T0 and T1

	Pretreatment				Posttreatment				Change with Treatment				
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	P value
pm-Ad 2	9.4	3.5	5.9	15.9	10.6	3.6	5.6	16.5	1.2	0.9	−0.1	2.5	.673
Postural variables													
CVT/EVT (°)	9.6	4.20	3.5	16	9.5	4.35	3.8	16	−1	0.5	−3.5	3.3	.893
Cervical inclination													
OPT/Ver (°)	2.3	3.2	−5.5	6	2.10	3.8	−6	6	−0.2	0.3	−1.6	2.3	.998
CVT/Ver (°)	2.2	3.9	−7	11.50	2.52	4.8	−6	11.3	0.32	0.7	−1.8	2.93	.498
EVT/Ver (°)	−6	5.1	−16	3	−6.7	5.65	−18.5	3	−0.7	1.2	−1.25	2.3	.468
Craniofacial inclination													
SN/Ver (°)	89	12	74	111	90.6	13.1	74	110.5	1.6	0.9	−1.5	3.3	.754
PP/Ver (°)	82	10	60	98	81.5	10.9	63	100	−0.5	0.9	−2.2	3.1	.086
MP/Ver (°)	61	6	43	78	60.5	6.98	44	75	−0.5	0.9	−1.7	2.6	.673
Craniocervical inclination													
SN/OPT (°)	81	5	74	94	83.2	4.90	75	92	2.2	0.9	−1.1	3.6	.687
SN/CVT (°)	86	5.40	77	98	86.8	5.15	79	99	0.8	0.3	−1.9	2.8	.876
PP/OPT (°)	75.3	4	68	97	75.30	4.40	70	84	0	0.9	−0.9	1.1	.865
PP/CVT (°)	78.5	4.5	70	89	78	4.5	71	88	−0.5	0.9	−2.5	2.10	.256
MP/OPT (°)	56	4.47	49	66	57.1	4.45	50	66	1.1	1.2	−1.7	3.2	.467
MP/CVT (°)	58	4.10	50	67	59.6	4.42	53	67	1.6	1.05	−1.85	1.83	.075

* Significant values ($P < 0.05$).

University of Chieti. Informed consent was obtained from all the parents.

Clinical recordings

Dental casts and 2 teleradiographs, taken in a mirror position as previously described,[27,28] were obtained from all 55 subjects, with the first record at the first visit and the second exactly 6 months later. Each film was traced and digitized. Ten radiographs were used for measurement of error. All angular measurements showed less than 0.75° of error, and all linear measurements showed less than 0.5 mm of error. The error for measurements on the dental casts was less than 0.3 mm. The variables studied were those previously analyzed in other studies on RME.[29] Postural variables are described in Figure 1.[30] The adequacy of the nasopharyngeal airway was expressed by the radiographic dimension pm-Ad 2, which is an approximate measure of the narrowest part of the nasopharyngeal airway.[8]

Statistical analysis

The Statistical Package for Social Sciences program (SPSS® Inc, Chicago, Ill) was used to perform the data analyses. Data were presented as means and standard deviations. The data were tested for normality using the 1-sample Kolmogorov-Smirnov test. Each data set met the required criteria for using parametric analyses. To determine whether the 2 subsamples of subjects were matched, a Student's *t*-test was performed on the means of the pretreatment dental and skeletal measurements. It was found that the 2 subsamples were equally matched because the totality of the measurements was not significantly different. A Student's paired *t*-test was then used to determine whether the changes between the groups and between the initial and final measurements were significant. Finally, a correlation matrix, using the Pearson correlation coefficient, was computed to evaluate the strengths of the straight-line relationship between the change in airway adequacy and the amount of maxillary expansion, the chronologic age, the amount of time that the appliance was activated, and the morphological and postural measurements of the face. Significance for all statistical tests was predetermined at $P < .05$.

RESULTS

Tables 1 and 2 describe the changes with treatment for the study and the control groups. Table 1 shows that changes in most measurements were statistically significant for the study group, whereas no significant change was observed in any of the variables in the control group (Table 2).

Changes in postural variables with treatment in the study and the control groups

No significant change was observed in the control group in any of the postural variables. There was a mean 3.19° significant increase in the cervical lordosis angle (CVT/EVT angle) in the study group ($P < .001$) from pre- to posttreatment (Table 1). This was more than treble and sig-

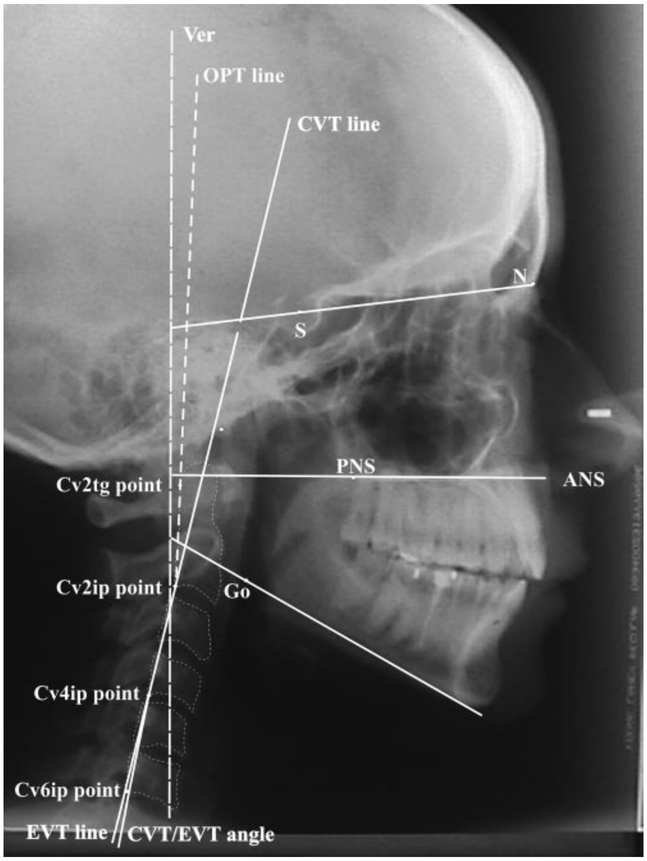

FIGURE 1. Cephalometric tracing representing the variables traced on the cervical column area. OPT (upper segment of the cervical column) is the line tangent to the posterior border of the odontoid process; CVT (middle segment of the cervical column) is the line between the most inferoposterior point of the second cervical vertebra (cv2ip) and that of the fourth cervical vertebra (cv4ip); EVT (lower segment of the cervical column) is the line between the most inferoposterior point of the fourth cervical vertebra (cv4ip) and that of the sixth cervical vertebra (cv6ip). CVT/EVT is the downward-opening angle between the CVT and EVT lines.

nificantly larger than the amount observed in the control group (Table 2) ($P < .0001$) (Table 3). There was a significant 3.67° backward inclination of the upper cervical column (OPT/Ver angle) in the study group ($P < .001$) from pre- to posttreatment (Table 1). This change was significantly higher when compared with the 0.2° observed in the control group ($P < .0001$) (Table 3). On the other hand, there were no significant changes in the lower as well as the middle cervical column inclination (CVT/Ver angle and EVT/Ver angle) (Table 1).

There was a significant flexion of the head in the study group (5.25°, $P < .0001$ for SN/Ver angle; 5.04°, $P < .0001$ for PP/Ver angle; 4.40°, $P < .0001$ for MP/Ver) from pre- to posttreatment (Table 1). All the 3 mean angles decreased more than 4° in the study group (Table 1), whereas they increased 0.5–1.6° in the control group (Table 2), with a statistically significant difference at $P < .0001$ (Table 3).

There was a significant decrease in the mean craniocervical angles (SN/OPT, PP/OPT, and MP/OPT angles) of 5.1°, 4.36°, and 5.12°, respectively, in the study group from pre- to posttreatment ($P < .0001$) (Table 1). On the other hand, subjects in the control group showed changes between 0° (no change) and 2.2° of the same craniocervical angles (SN/OPT, PP/OPT, and MP/OPT angles) (Table 2). The differences in craniocervical angulations after treatment were significantly lower in the control group than in the study group ($P < .0001$) (Table 3).

Correlations of variables

The significant increase in pm-Ad 2 observed in the study group was not correlated to the amount of time that the RME appliance was activated, the chronologic age, or any of the measurements indicating maxillary and mandibular morphology on a sagittal plane, but it was mildly correlated to the change in craniocervical angulation (SN/OPT angle) ($r = 0.61$ at $P < .001$).

DISCUSSION

Only female subjects were included in the study because the curvature of the cervical spine has been related to sex, where male subjects more often exhibit a straight curvature and female subjects more often exhibit a partial reverse curvature.[7,9] To avoid false conclusions about the effective changes in cervical curvature, only girls were included in the sample.

The radiographs were taken with the occlusion in habitual position with the appliance out of the mouth, both before and after treatment. At present, most studies about postural changes associated with the wearing of an oral appliance have been carried out with the devices inserted.[31,32] In contrast to those investigations, we chose to examine the real therapeutic effect and not the cervical spine posture when the mandible is positioned in a particular relation with the maxillary base (as achieved through the oral appliance). Thus, our data indicate the real changes in postural assessment after therapy and not the mechanical effect of the oral appliance.

In this study the radiographs were obtained in mirror position. It has been shown previously that the natural head position obtained with a particular device, incorporated into a pair of eyeglass frames, including 2 tilt sensors to measure pitch and roll of the head, showed a high reproducibility.[33] In another study, natural head position was obtained by using an inclinometer, which showed a good reproducibility over time (2 years), and a mean method error of 1.1° for sagittal and transversal measurements.[34] In this study we did not use any particular device to obtain natural head position because the reproducibility of the method (mirror position) was estimated accurately in a preliminary test.

According to the aims of this study, the most important finding was that at posttreatment a significantly higher CVT/EVT angle was observed in patients treated with

TABLE 3. Comparison of Differences in the Amount of Change With Treatment Between the Study and the Control Groups

	Study Group				Control Group				
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	*P* value
pm-Ad 2	5.3	1.9	−0.5	8.2	1.2	0.9	−0.1	2.5	.0001*
Postural variables									
CVT/EVT (°)	3.19	4.20	3.5	3.78	−1	0.5	−3.5	3.3	.0001*
Cervical inclination									
OPT/Ver (°)	3.67	3.72	3.02	3.84	−0.2	0.3	−1.6	2.3	.0001*
CVT/Ver (°)	0.48	1.49	−0.8	0.93	0.32	0.7	−1.8	2.93	.465
EVT/Ver (°)	0.65	1.30	0.10	0.02	−0.7	1.2	−1.25	2.3	.895
Craniofacial inclination									
SN/Ver (°)	−5.25	−9.5	10.5	7.2	1.6	0.9	−1.5	3.3	.0001*
PP/Ver (°)	−5.04	3.30	4.2	7.8	−0.5	0.9	−2.2	3.1	.0001*
MP/Ver (°)	−4.40	1.15	−9.9	4.9	−0.5	0.9	−1.7	2.6	.0001*
Craniocervical inclination									
SN/OPT (°)	−5.1	2.40	−9.5	3.2	2.2	0.9	−1.1	3.6	.0001*
SN/CVT (°)	−0.51	0.9	−8.5	3.5	0.8	0.3	−1.9	2.8	.065
PP/OPT (°)	−4.36	2.15	−8.5	4	0	0.9	−0.9	1.1	.0001*
PP/CVT (°)	0.42	1.15	0.5	1.10	−0.5	0.9	−2.5	2.10	.673
MP/OPT (°)	−5.12	2.50	1.2	9.5	1.1	1.2	−1.7	3.2	.0001*
MP/CVT (°)	0.29	1.05	−0.90	1.80	1.6	1.05	−1.85	1.83	.063

* Significant values ($P < 0.05$).

RME as compared with the control group (Tables 1 through 3). This increase probably was associated with the backward inclination of the middle segment of the cervical spine (CVT/Ver angle) and the forward inclination of the lower segment of the cervical column (EVT/Ver angle), although no significant changes in the inclination of the middle and the lower segments were observed in the study or the control group (Tables 1 and 2).

In addition, subjects in the study group showed a decreased craniocervical angulation of about 5° and a flexion of the head after therapy (Table 1), whereas control subjects exhibited no significant changes (Table 2). The flexion of the head was of the same magnitude when measured to the true vertical (SN/Ver angle) and to the odontoid tangent (SN/OPT angle), suggesting that anterior tipping of the head had taken place when maxillary expansion was obtained.

Our results are in accord with those of Solow et al[8] and Solow and Greve[6] because they also observed a significant relationship between a small pm-Ad 2 distance and a large craniocervical angle. They also are in accord with those of Wenzel et al,[19] who observed a significant decrease in the craniocervical angulation of about 2.3° in 37 mouth-breathing children with bronchial asthma treated with budesonide to improve respiratory function.

The common interpretation of these results is that head extension is often seen in mouth breathers and could be an important physiologic compensation for nasal airway inadequacy, as hypothesized by Ricketts.[3] Although our findings confirm this hypothesis, it is very uncertain whether these changes in head posture are clinically relevant. Long-term observations are needed to clarify the effect of flexing of the head on craniofacial variables. In our investigation, correlations were also found between changes in nasopharyngeal airway adequacy and postural variables, but the correlation was statistically significant only for the craniocervical angulation. This corresponds with the results of other studies.[6,12]

A possible hypothesis about the role of RME in postural changes may be that the increased palatal diameter results in the consequent enlargement of the pharyngeal airway space. This enlargement leads to improvement in respiratory function and the consequent flexion of the head upon the cervical column with an increase of the cervical lordosis angle and a decrease of the craniocervical angulations. In this mechanism the muscular-neural network could play an important role. Several researchers underlined the existence of muscular-neural connections between oral functions and the neck area, mostly regarding the reflex connections existing between the morphological structure of the face (temporomandibular joint status and, presumably, mandibular position in vertical as in sagittal direction) and the fusimotor-muscle spindle system of dorsal neck muscles,[35] perhaps because of the neurophysiological principles of convergence and sensitization.[36]

From a clinician's point of view, our observations suggest the need for a periodic review to evaluate the changes occurring in the cervical and head posture during orthodontic treatment with RME, although the clinical importance of these results is yet to be clarified.

CONCLUSIONS

Within the limits set by the sample examined, the findings of this study suggest that improvement of nasopharyngeal airway adequacy associated with RME was mildly associated with a decreased craniocervical angle, an increased cervical lordosis angle, and a flexion of the head.

The primary limitation of this study is that therapeutic evaluations were made without the benefit of follow-up data, and this should be investigated further. In addition, rotational or sideways components of cervical column curvature changes were not known because the examination was made in the sagittal plane. This could have resulted in an underestimation of the postural changes in the present investigation.

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