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Evaluation of cervical posture following palatal expansion: a 12-month follow-up controlled study

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SUMMARY This study evaluated the effects of rapid palatal expansion (RPE) on nasopharyngeal airway size, head posture, and cervical curvature angle in children with nasal obstruction. The patients were 45 female subjects (8–15 years of age) who had a reduced nasopharyngeal airway size and were subjectively assessed as being mouth breathers and requiring palatal expansion. They were randomly allocated to one of two groups: 23 subjects in the first group were treated with RPE, while the 22 subjects in the other group were monitored for approximately 14 months prior to commencing therapy, and became untreated controls. Lateral skull radiographs, taken in the natural head position, were obtained at the first visit (T0) and 6 (T1) and 12 (T2) months later for all subjects. The differences between the cephalometric variables at baseline and after 6 and 12 months were evaluated with a one-way repeated measures analysis of variance. Where significant interactions were found, a Bonferroni corrected paired Student's *t*-test was performed for pairwise comparisons. Changes in cephalometric variables within the experimental groups were tested by paired Student's *t*-tests as a *post hoc* procedure. Finally, a correlation matrix, using the Pearson correlation coefficient, was computed in order to evaluate the relationship between the change in airway adequacy and (1) the amount of maxillary expansion, (2) chronological age, (3) the amount of time that the appliance was activated, and (4) morphological and postural measurements of the face.

At T1, children under active treatment showed a statistically significant increase in nasopharyngeal airway size, cervical curvature angle, and flexion of the head, together with a significant decrease in craniocervical angulation (all $P < 0.05$). These changes were all found to be stable at T2. No significant changes were seen in the control group. The correlation coefficients indicated a significant correlation between nasopharyngeal airway size and craniocervical angulation (SN/OPT angle; $r = -0.61$, $P < 0.05$).

The findings indicate that RPE is capable of increasing nasopharyngeal airway size in young females, which results in a decrease in craniocervical angulation. Clinically, the findings seem to suggest that improvement of respiratory function could result in a change in head posture.

Introduction

Researchers are generally in agreement that respiratory airway function influences facial morphology and head posture (Carlsöö and Leijon, 1960; Bench, 1963; Solow, 1966; Ricketts, 1968; Linder-Aronson, 1970, 1974, 1975; Solow and Kreiborg, 1977; Solow and Tallgren, 1977; Solow *et al.*, 1982, 1984; Hellsing *et al.*, 1987; Huggare and Laine-Alava, 1997). Ricketts (1968) hypothesized the relationship between head posture and respiratory functional demands, when he reported that extension of the head was a functional response facilitating oral breathing to compensate for nasal obstruction.

Solow and Kreiborg (1977) and Solow *et al.* (1982) confirmed the hypothesis involving neuromuscular feedback and passive stretching of the soft tissue layer covering the face and neck. According to this theory, children with airway obstruction would be expected to show increased craniocervical angulation (Solow and Greve, 1979; Solow *et al.*, 1984), as supported by Tourne and Schweiger (1997) in their study, which found an immediate increase in craniocervical angulation of approximtely 5 degrees when there was total nasal obstruction.

Based on this evidence, several researchers have reported significant changes in head posture and craniocervical angulation after various types of therapy aimed at improving nasal respiratory function. Longitudinal studies, for example Solow and Greve (1979) and Woodside and Linder-Aronson (1979), observed a reduction of approximately 2 degrees in craniocervical angulation 2 months after adenoidectomy. In addition, the differences in head posture between children with pathology and a control group disappeared (Woodside and Linder-Aronson, 1979). Wenzel *et al.* (1983) undertook a longitudinal, double blind, controlled study and showed that pharmacological treatment with Budesonide improved respiratory function and caused a decrease in craniocervical angulation, in addition to a decrease in nasal resistance.

However, information is still lacking on the effects of rapid palatal expansion (RPE) on head posture and craniocervical angulation, despite the fact that the typical malocclusion associated with respiratory obstruction is characterized by a reduced transverse palatal dimension (McNamara, 1981) and RPE is one of the primary treatments for maxillary expansion. Treatment outcomes associated with RPE have been investigated but have tended to focus on changes in facial morphology (Staggers, 1994) and respiratory function (Hershey *et al.*, 1976; Piccini *et al.*, 1989; Loreille and Béry, 1997) but without consideration of head posture and craniocervical angulation.

Therefore, the aim of this study was to evaluate RPE treatment outcomes, with emphasis on changes in head posture and craniocervical angulation. The results for this group were compared with those of untreated controls.

Subjects and methods

The study was approved by the Ethics Committee of the University of Dentistry, Chieti, Italy, and informed consent was obtained from all parents.

The sample included 45 children [all females, mean age 8.1 years standard deviation (SD) ± 2.0; range 8–15 years] undergoing treatment at the Department of Orthodontics and Gnathology, University of Chieti, Italy. The criteria for selection were based on gender, European origin, reduced nasopharyngeal airway adequacy (as determined from a lateral cephalogram), a history of mouth breathing as confirmed by the parents, and a need for palatal expansion. Exclusion criteria were nasal allergic conditions, airway obstruction due to enlarged adenoids, or a history of previous orthodontic treatment.

The patients were randomly divided into two groups. Those in the first group were scheduled to begin treatment soon after the first visit (this 'study group' comprised 23 children). Approximately 14 months after the first visit, the second group which comprised 22 children began therapy (the 'control group'). The subjects in the control group did not undergo any type of treatment (orthodontic and/or pharmacological therapy) during the observation period.

Fifteen patients in the study group had an anterior and/or posterior crossbite, and eight dental compensation for the transverse discrepancy but without an apparent crossbite. In the control group, 13 patients had an anterior and/or posterior crossbite and nine a transverse discrepancy with no apparent crossbite.

The expansion regimen involved four turns of the RPE screw for the first day, followed by two turns per day until the required expansion was achieved (1 turn = 0.2 mm). After expansion, the appliance (R.E.P.®, Dentaurum Italia s.r.l., Funo, Bologna, Italy) was left *in situ* for a mean period of 4.7 ± 0.8 months (range 3.6–5.9 months). The expansion and retention regimens were decided by one operator (Simona Tecco), based on clinician preference and the diagnoses of the patients' individual malocclusions.

Clinical recordings

Two teleradiographs, taken in the mirror position (Mølhave, 1958; Solow and Tallgren, 1971; Festa *et al.*, 2003), were obtained for all 55 subjects at the first visit (T0), then again after 6 (T1) and 12 (T2) months. Each film was traced and digitized by one operator (ST). Ten radiographs were used for measurement of error, as previously described (Festa *et al.*, 2003). All angular measurements showed errors of less than 0.75 degrees and all linear measurements less than 0.5 mm. The variables are shown in Figure 1 (Solow, 1966; Hellsing *et al.*, 1987; Festa *et al.*, 2003). The size of the nasopharyngeal airway was expressed by the radiographic dimension pm-Ad

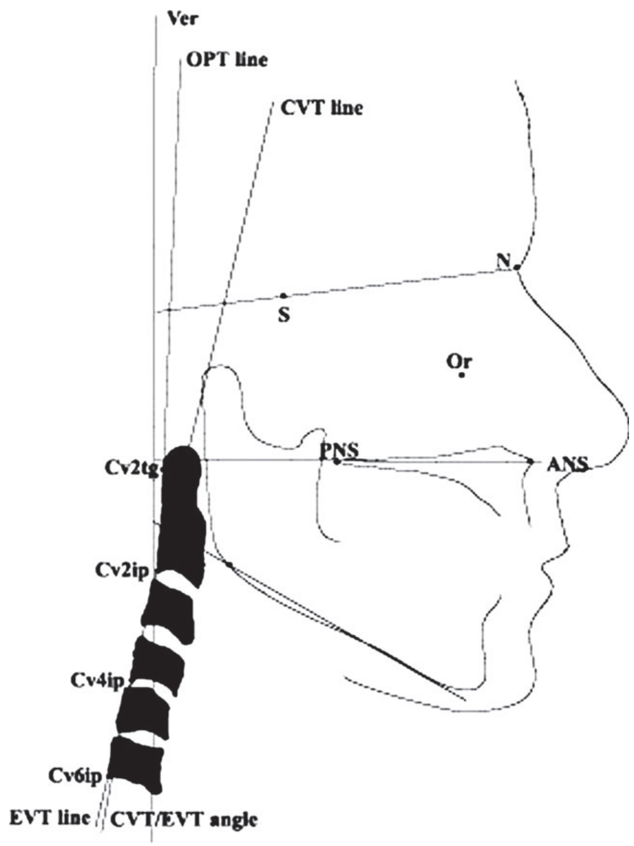

Figure 1 The variables traced on the lateral skull radiographs. cv2tg: the tangent point of the superior, posterior extremity of the odontoid process of the second cervical vertebra. cv2ip: the most infero-posterior point on the body of the second cervical vertebra. cv4ip: the most infero-posterior point on the body of the fourth cervical vertebra. cv6ip: the most infero-posterior point on the body of the sixth cervical vertebra. Lines: CVT: the upper part of the cervical spine. A line through cv2tg and cv4ip. EVT: the lower part of the cervical spine. A line through cv4ip and cv6ip. OPT: odontoid line. A line through cv2tg and cv2ip. SN: anterior cranial base. A line through point S and point N. PP: palatal plane. A line through posterior nasal spine (pns) and anterior nasal spine (ans). MP: mandibular plane. A tangent line to the inferior border of the mandible. Variables: CVT/EVT: cervical lordosis angle. The downward opening angle between the CVT and EVT line. OPT/Ver: odontoid angle. The downward opening angle between the OPT and true vertical lines. EVT/Ver: lower cervical column angle. The downward opening angle between the EVT and true vertical lines. CVT/Ver: upper cervical column angle. The downward opening angle between the CVT and true vertical lines. SN/Ver: the downward opening angle between the SN and true vertical lines. PP/Ver: the downward opening angle between the palatal and true vertical lines. MP/Ver: the downward opening angle between the mandibular and true vertical lines. SN/OPT: the downward opening angle between OPT and SN lines. SN/CVT: the downward opening angle between CVT and SN lines. PP/OPT: the downward opening angle between OPT and palatal lines. PP/CVT: the downward opening angle between CVT and palatal lines. MP/OPT: the downward opening angle between OPT and mandibular lines. MP/CVT: the downward opening angle between CVT and mandibular lines.

2, which is an approximate measure of the narrowest part of the nasopharyngeal airway (Solow *et al.*, 1984).

Statistical analysis

In order to assess errors due to landmark identification, duplicate measurements were made of 10 radiographs as described by Hellsing *et al.* (1987). The error variance was calculated using Dahlberg's formula (1940)

$$\delta = \sqrt{\left(\sum \delta^2/2N\right)},$$

where *d* is the difference between the first and the second measurement and *N* the number of double registration.

The Statistical Package for Social Sciences (SPSS® Inc., Chicago, Illinois, USA) was used for data analysis. The data were tested for normality by means of the one-sample Kolmogorov–Smirnov test and each data set met the required criteria for using parametric analyses. The data are therefore presented as means and SDs. In order to determine if the two groups of subjects were matched, a Student's *t*-test was performed on the means of the pre-treatment skeletal measurements. It was found that the groups were comparable and there were no significant differences. The differences between the cephalometric variables at T0, T1, and T2 were evaluated with a one-way repeated measures analysis of variance. If significant interactions were found, a Bonferroni corrected paired Student's *t*-test was performed for pairwise comparisons. Changes in cephalometric variables within the experimental groups were tested by paired Student's *t*-tests as a *post hoc* procedure. Finally, a correlation matrix, using the Pearson correlation coefficient, was computed in order to evaluate the relationship between the change in airway adequacy and the amount of maxillary expansion, chronological age, the amount of time that the appliance was activated, and postural measurements of the face. Significance for all statistical tests was set at $P < 0.05$.

Results

The mean pre-treatment ANB value was 3.8 degrees (SD ± 1.52). Tables 1 and 2 describe the changes with treatment for the study and control groups, and Tables 3 and 4 the differences between the study and the control group at T1 and T2, respectively.

At T1, changes in most skeletal measurements were statistically significant for the study group, and were stable at T2 (Table 1), whereas no significant changes were observed for any of the variables in the control group (Table 2).

Changes in the study and control groups in postural variables

There was a significant increase of 3.19 degrees in the cervical curvature angle (CVT/EVT angle) in the study group at T1 ($P < 0.05$). The changes observed at T1 were also stable at T2 (Table 1). No significant differences were observed in the control group for any of the postural variables (Table 2).

At T1, there was also a significant backward inclination of the upper cervical column (OPT/Ver angle) from pre- to post-treatment in the study group (mean increase of 3.67 degrees; $P < 0.05$; Table 1). This change was significantly greater than the 0.2 degrees decrease observed in the control group (difference between the two groups of $P < 0.05$; Table 3). On the contrary, there was no significant change in the lower or middle cervical column inclination (CVT/Ver angle and EVT/Ver angle) and no significant changes were observed at T2 (Tables 1 and 2).

From T0 to T2, there was a significant flexion of the head in the study group (5.25 degrees for SN/Ver angle, 5.04 degrees for PP/Ver angle, 4.40 degrees for MP/Ver; all $P < 0.05$; Table 1). The changes in the control group were less (approximately 0.5 to 1.5 degrees; Table 2), with a statistically significant difference between the two groups ($P < 0.05$; Table 3). No significant changes were observed at T2.

There was a significant decrease of the mean craniocervical angles (SN/OPT, PP/OPT, and MP/OPT) of 5.1, 4.36, and 5.12 degrees, respectively, in the study group at T1 ($P < 0.05$; Table 1). The subjects in the control group showed changes of 0 to 2.2 degrees (Table 1), with a significant difference at $P < 0.05$ (Tables 3 and 4). No significant changes were observed at T2.

Correlations of variables

The significant increase in pm-Ad 2 in the study group was not significantly correlated with the amount of time that the RPE appliance was activated, chronological age, or any of the measurements indicating maxillary and mandibular morphology in the sagittal plane, but it was significantly correlated with the change in craniocervical angulation (SN/OPT angle; $r = -0.61$, $P < 0.05$).

Discussion

Only females were included in the study since curvature of cervical spine has been shown to be related to gender, with males more often exhibiting a straight curvature and females a partly reversed curvature (Solow *et al.*, 1982; Hellsing *et al.*, 1987).

The radiographs were taken in habitual occlusion, with the appliance removed, both pre- and post-treatment. At present, most studies on postural changes associated with the wearing of an oral appliance have been carried out with the devices *in situ* (Moya *et al.*, 1994; Miralles *et al.*, 1997). In contrast to those investigations, the current study should show the real therapeutic effect.

The most important finding was that, post-treatment, a significantly higher CVT/EVT angle was observed in patients treated with RPE, as compared with the control

Table 1 Treatment changes in the study group ($n = 23$). Cephalometric and dental casts measurements before treatment (T0) and 6 (T1) and 12 (T2) months after the first visit.

	T0				T1					T2					
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	T1 versus T0 (*P* value)	Mean	SD	Minimum	Maximum	T2 versus T1 (*P* value)	T2 versus T0 (*P* value)
pm-Ad 2	10.5	3.4	6.4	16.8	15.8	3.5	9.8	20.2	*	15	3	9	24	NS	*
Postural variables															
CVT/EVT (°)	9.77	4.15	3.5	16	12.96	4.30	5.5	18	*	11	3.50	3	21	NS	*
Cervical inclination															
OPT/Ver (°)	2.08	3.68	−6	6	5.75	3.82	−6	6	*	4.5	1.2	−6	8	NS	*
CVT/Ver (°)	2.48	4.10	−6	11.50	2.96	4.71	−5	10	NS	2.5	3.2	−3	12	NS	NS
EVT/Ver (°)	−6.85	5.73	−18.5	3	−7.5	6.9	−18.5	3	NS	−6	7.5	−15	3	NS	NS
Craniofacial inclination															
SN/Ver (°)	90.75	12.95	73	110	85.5	14.67	73	113	*	85	13	68	114	NS	*
PP/Ver (°)	81.21	11.11	62	99	86.25	9.65	72	100	*	85.5	9.2	71	98	NS	*
MP/Ver (°)	60.80	7.89	45	75	56.40	8.32	43	75	*	55.4	7.3	41	76	NS	*
Craniocervical inclination															
SN/OPT (°)	82.5	4.96	75	93	77.4	5.09	72	92	*	76	6.3	70	93	NS	*
SN/CVT (°)	86.71	5.30	78	99	86.20	4.96	72	93	NS	85	4.3	71	92	NS	NS
PP/OPT (°)	75.46	4.50	69	83	71.10	4.40	72	85	*	70	4.2	70	83	NS	*
PP/CVT (°)	78.75	4.74	71	88	79.17	5.62	71	88	NS	78	5.1	69	85	NS	NS
MP/OPT (°)	56.37	4.47	49	66	51.25	5.10	44	66	*	50	4.5	42	65	NS	*
MP/CVT (°)	59.21	4.14	53	68	59.5	4.62	53	67	NS	58	3.5	51	66	NS	NS

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

Table 2 Changes in the control group ($n = 22$). Cephalometric and dental casts measurements at the first visit (T0) and 6 (T1) and 12 (T2) months after the first visit.

	T0				T1					T2					
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	T1 versus T0 (*P* value)	Mean	SD	Minimum	Maximum	T2 versus T1 (*P* value)	T2 versus T0 (*P* value)
pm-Ad 2	9.4	3.5	5.9	15.9	10.6	3.6	5.6	16.5	NS	10	3.5	6	17	NS	NS
Postural variables															
CVT/EVT (°)	9.6	4.20	3.5	16	9.5	4.35	3.8	16	NS	9	4.1	3.5	15	NS	NS
Cervical inclination															
OPT/Ver (°)	2.3	3.2	−5.5	6	2.10	3.8	−6	6	NS	3	4	−3	7	NS	NS
CVT/Ver (°)	2.2	3.9	−7	11.50	2.52	4.8	−6	11.3	NS	3.1	3.5	−4	13	NS	NS
EVT/Ver (°)	−6	5.1	−16	3	−6.7	5.65	−8.5	3	NS	−5	6	−16	4	NS	NS
Craniofacial inclination															
SN/Ver (°)	89	12	74	111	90.6	13.1	74	110.5	NS	89	12	73	112	NS	NS
PP/Ver (°)	82	10	60	98	81.5	10.9	63	100	NS	80.5	10	65	99	NS	NS
MP/Ver (°)	61	6	43	78	60.5	6.98	44	75	NS	59	7.1	42	77	NS	NS
Craniocervical inclination															
SN/OPT (°)	81	5	74	94	83.2	4.90	75	92	NS	81	3.7	72	94	NS	NS
SN/CVT (°)	86	5.40	77	98	86.8	5.15	79	99	NS	86	5.2	78	98	NS	NS
PP/OPT (°)	75.3	4	68	97	75.30	4.40	70	84	NS	73	4.2	70	83	NS	NS
PP/CVT (°)	78.5	4.5	70	89	78	4.5	71	88	NS	79	4.7	70	89	NS	NS
MP/OPT (°)	56	4.47	49	66	57.1	4.45	50	66	NS	56	3	49	66	NS	NS
MP/CVT (°)	58	4.10	50	67	59.6	4.42	53	67	NS	59	3.5	52	66	NS	NS

Table 3 Comparison of differences in the amount of change between the study and the control groups at 6 months.

	Study group (*n* = 23)				Control group (*n* = 22)				*P* value
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	
pm-Ad 2	5.3	1.9	−0.5	8.2	1.2	0.9	−0.1	2.5	*
Postural variables									
CVT/EVT (°)	3.19	4.20	3.5	3.78	−1	0.5	−3.5	3.3	*
Cervical inclination									
OPT/Ver (°)	3.67	3.72	3.02	3.84	−0.2	0.3	−1.6	2.3	*
CVT/Ver (°)	0.48	1.49	−0.8	0.93	0.32	0.7	−1.8	2.93	NS
EVT/Ver (°)	0.65	1.30	0.10	0.02	−0.7	1.2	−1.25	2.3	NS
Craniofacial inclination									
SN/Ver (°)	−5.25	9.5	10.5	7.2	1.6	0.9	−1.5	3.3	*
PP/Ver (°)	−5.04	3.30	4.2	7.8	−0.5	0.9	−2.2	3.1	*
MP/Ver (°)	−4.40	1.15	−9.9	4.9	−0.5	0.9	−1.7	2.6	*
Craniocervical inclination									
SN/OPT (°)	−5.1	2.40	−9.5	3.2	2.2	0.9	−1.1	3.6	*
SN/CVT (°)	−0.51	0.9	−8.5	3.5	0.8	0.3	−1.9	2.8	NS
PP/OPT (°)	−4.36	2.15	−8.5	4	0	0.9	−0.9	1.1	*
PP/CVT (°)	0.42	1.15	0.5	1.10	−0.5	0.9	−2.5	2.10	NS
MP/OPT (°)	−5.12	2.50	1.2	9.5	1.1	1.2	−1.7	3.2	*
MP/CVT (°)	0.29	1.05	−0.90	1.80	1.6	1.05	−1.85	1.83	NS

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

Table 4 Comparison of differences in the amount of change between the study and the control groups at 12 months.

	Study group (*n* = 23)				Control group (*n* = 22)				*P* value
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	
pm-Ad 2	−0.8	1.1	−2.3	3.9	−0.6	0.6	−1.3	0.6	NS
Postural variables									
CVT/EVT (°)	−1.96	0.8	−4.1	3.9	−0.5	0.3	−1.1	0.6	NS
Cervical inclination									
OPT/Ver (°)	−1.25	1.2	−3.9	3.9	0.9	0.4	0.1	1.5	NS
CVT/Ver (°)	−0.46	0.6	−1.7	1.3	0.68	0.5	−2.2	2.3	NS
EVT/Ver (°)	1.5	0.9	−2.4	3.1	1.7	1.1	−1.5	2.5	NS
Craniofacial inclination									
SN/Ver (°)	−0.5	0.8	−2.1	3.1	−1.6	0.8	−2.9	3.2	NS
PP/Ver (°)	−1.25	0.7	−2.6	3.2	−1	0.7	−2.3	3.3	NS
MP/Ver (°)	−1	0.8	−2.2	2.1	−1.5	0.8	−2.8	2.7	NS
Craniocervical inclination									
SN/OPT (°)	−1.4	0.1	−1.9	2.1	−2.2	0.8	−3.5	1.2	NS
SN/CVT (°)	−1.2	0.9	−2.1	2.5	−0.8	0.3	−1.9	2.8	NS
PP/OPT (°)	−1.1	1.5	−2.9	3.1	−2.3	0.9	−3.9	1.1	NS
PP/CVT (°)	−1.17	0.8	−0.5	2.1	1	0.9	−2.5	2.10	NS
MP/OPT (°)	−1.25	1.3	−2.7	3.8	−1.1	1.2	−2.7	2.8	NS
MP/CVT (°)	−1.5	0.9	−2.9	3.1	−0.6	1.05	−2.1	1.9	NS

NS, not significant.

group (Tables 1–4). This increase was probably associated with a backward inclination of the middle segment of the cervical spine (CVT/Ver angle) and 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 control group (Tables 1 and 2).

After therapy, the subjects in the study group showed a decreased craniocervical angulation of approximately 5 degrees and a flexion of the head (Table 1), while the control subjects exhibited no significant changes (Table 2). 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; Table 2), suggesting that anterior tipping of the head had taken place following palatal expansion. These results are in agreement with those of Solow and Greve (1979) and Solow *et al.* (1984) who observed a significant relationship between a small pm-Ad 2 distance and a large craniocervical angle. The findings are also in agreement with Wenzel *et al.* (1983) who reported a significant decrease in craniocervical angulation (about 2.3 degrees) in 37 children with bronchial asthma, treated with Budesonide to improve respiratory function. The common interpretation of these results is that head extension is seen in mouth breathers and could be an important physiological compensation for nasal airway inadequacy, as first hypothesized by Ricketts (1968). Although the present findings confirmed this hypothesis, it is uncertain whether these changes in head posture are of a clinically relevant magnitude. The results showed that the postural and morphological changes that occurred at T1 remained stable at T2 (Table 1), suggesting a long-term effect. However, as most of the patients were wearing a fixed orthodontic appliance at that time, this could have influenced the results. Evaluation of cervical and morphological variables in the same subjects, after debonding, will be investigated since long-term observations are needed in order to clarify the effect of head flexure on craniofacial variables.

In the present study, correlations between changes in nasopharyngeal airway adequacy and postural variables were also investigated. However, the only statistically significant correlation was for craniocervical angulation. This is in agreement with the results of Solow and Greve (1979) and Solow and Tallgren (1976).

A possible hypothesis for the role of RPE in postural changes may be that the increase in palatal width results in enlargement of the pharyngeal airway space, improvement in respiratory function and flexion of the head on the cervical column, with an increase in the cervical curvature angle and a decrease in craniocervical angulation. In this mechanism, the muscular–neural network could play an important role. Several researchers have 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), and the fusi-motor-muscle spindle system of dorsal neck muscles, (Miralles *et al.*, 2002) perhaps because of the neurophysiological principles of convergence and sensitization (Visscher *et al.*, 2001).

Although the clinical importance of these results is yet to be clarified, the present observations indicate that periodic reviews should be carried out to evaluate changes occurring in cervical and head posture during RPE. The findings seem to suggest that the improvement of respiratory function could provide a change in cervical posture.

Conclusion

Improvement of nasopharyngeal airway adequacy as a result of RPE is associated with a decrease in craniocervical angle and an increase in cervical curvature angle and head flexion. It must be noted, however, that rotational and/or lateral components of cervical column curvature changes were not possible, because the examination was in the sagittal plane. This could have resulted in an underestimation of the postural changes in the present investigation.

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