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Changes in head posture after rapid maxillary expansion in patients with nasopharyngeal obstruction

Kjurchieva-Chuchkova, Gabriela *; Kanurkova, Lidija *; Bajraktarova Miševska, Cvetanka *

** Department of Orthodontics, Faculty of Dentistry, Ss. Cyril and Methodius University of Skopje, FYR of Macedonia*

ABSTRACT

Introduction: Nasopharyngeal obstruction is an important etiologic factor in the development of an extreme vertical growth facial pattern, and insufficient transversal growth of the maxilla. The treatment outcomes associated with rapid maxillary expansion in the literature are mainly discussed in terms of changes in dentofacial morphology, without special reference to changes in the pharyngeal airway, the position of the mandible, hyoid bone and the tongue.

Aim: The aim of this study was to evaluate the effects of rapid maxillary expansion (RME), on changes in head posture and airway dimension.

Materials and methods: The cephalometric evaluation was conducted on thirty lateral cephalograms of patients with nasopharyngeal obstruction (mean age 9.11 years; standard deviation (SD) ± 2.0; range 8-14 years) treated with appliance for rapid maxillary expansion. Patients were randomly divided into two groups: 1) study group comprised of 15 patients treated with RME immediately after the first visit; 2) a control group comprised of 15 subjects monitored for approximately 12 months prior to commencing therapy, who became untreated controls. Lateral cephalograms, taken in the natural head position, were obtained at the first visit and 6 months later for all subjects. Six angular measurements were measured to describe craniocervical angulation, and five linear measurements were measured to describe airway dimension.

Results: The investigated group treated with RME shows a statistically significant decrease in craniocervical angulation, especially at the angle of interaction between palatal plane and the tangent odontoid processus (4.07 degrees, for PP/OPT angle) and angle interaction between palatal plane and the tangent of cervical vertebra (4.95 degrees for PP/CVT angle). Airway dimension in the treated group increased, especially at the levels PNS-ad1 (2.52 mm), ve-pve (2.97 mm), and uv-puv (2.88 mm). No significant changes were observed in the control group.

Conclusions: RME is a treatment procedure capable of providing increased nasopharyngeal airway adequacy, changing the head posture as well as position of the mandible and tongue, creating the conditions for myofunctional balance and proper development of craniofacial complex and changing mode of respiration.

Key words: nasopharyngeal obstruction; head posture; airway dimension; rapid maxillary expansion.

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INTRODUCTION

The respiratory function, as one of the four basic functions of the orofacial complex, represents a significant etiologic factor affecting the growth and development of craniofacial structures. If we consider the doctrine of Moss's theory of "functional matrix", which is based on the principle that the individual facial growth and development is closely related to the functional activity of various components of the head and neck, [1] oral respiration results in alteration on the forces affecting the facial skeleton as well as in malocclusions.

Dentomaxillofacial complex represents a single compact unit, with nasopharynx as an integral part. Airways, type of respiration and craniofacial system are closely related and connected to the extent that, during the growth and development, the morphology

Corresponding Author:
Gabriela Kjurchieva-Chuchkova
Department of Orthodontics, Faculty of Dentistry,
Ss. Cyril andMethodius University of Skopje,
Nikola Parapunov 2/18, Skopje, FYR of Macedonia
e-mail: dr_cuckova@yahoo.com

and function are interwoven and cannot be analyzed separately. The positions of the mandible, tongue, head and hyoid bone are primary determinants for respiratory functional demands, and are thus very important for the proper performance of the respiratory function. Based on the respiratory functional demands, extension of the head will lift the head away from the hyo-mandibular complex, as a functional response facilitating oral breathing to compensate for nasal obstruction. [2-4] Ricketts (1968) points out that the extension of the head is a defensive compensatory functional mechanism that serves to maintain the capacity of nasopharyngeal airways, and using a separate base of tongue and soft palate (the place of the most pronounced constriction) facilitates oral breathing as a compensatory response to nasal obstruction. [5]

In pathophysiological conditions, anatomically narrow airways represent a predisposing factor of obstruction of the upper airways. [4] The main issue that orthodontists should have in mind when they develop their treatment plan is: "Was the improper function of respiration the main cause for malocclusion, or vice versa, did the dentofacial anomalies become a factor for narrowing the pharyngeal dimension and be the predisposing factor for obstruction of the upper airways and disruption of the breathing function?"

Typical figure for children with impaired type of breathing due to chronic nasopharyngeal obstruction is the adenoid face, characterized by open mouth posture, hypotonic lips, reduced transverse dimension of the maxilla, extreme compression of the maxillary dental arch with high palatal vault, frequently with mandibular retrognatism, increased anterior and especially increased lower facial high.

Rapid maxillary expansion (RME) is one of the main methods for the correction of insufficient transverse dimension of the maxillary base or posterior cross bite. [6]

The treatment outcomes associated in the literature with applied RME are mainly discussed in terms of changes in dentofacial morphology, nasal resistance and nasal dimensions. [7-14] Still, there are some studies concerning changes in the pharyngeal airway and head posture before and after rapid maxillary treatment. [15-22]

The aim of this study was to evaluate the effects of RME on the changes in head posture and airway dimension.

MATERIALS AND METHODS

The study was approved by the Teaching and Science Research Council of the University "Ss. Cyril and Methodius", Skopje, Republic of Macedonia. Written permission has been obtained from the parents of the children included in the study. None of the patients had received previous orthodontic treatment.

The cephalometric evaluation was conducted on thirty lateral cephalograms of patients (mean age 9.11 years; standard deviation (SD) ± 2.0; range 8-14 years), from the Department of Orthodontics at P.H.O. University Dental Clinical center "St. Panteleimon", in Skopje, Republic of Macedonia. The inclusion criteria comprised of children with: bilateral posterior cross bites scheduled to receive RME as an integrative part of their comprehensive orthodontic treatment, nasopharyngeal obstruction, confirmed by otorhinolaryngology specialist.

Patients were randomly divided into two groups: 1) group 1 (experimental, n = 15) patients treated with RME immediately after the first visit; 2) group 2 (control, n = 15) patients in the other group were monitored for approximately 12 months prior to commencing therapy, and became untreated controls.

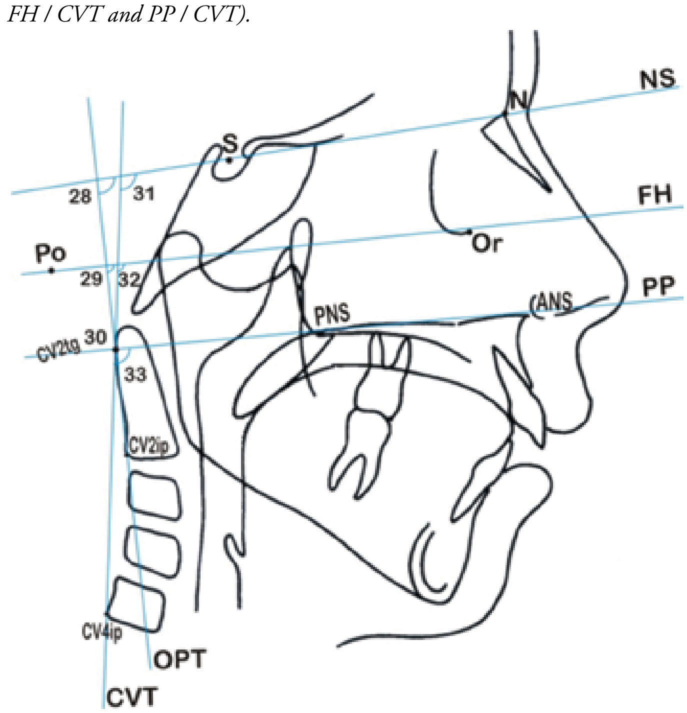
All the patients were treated with a hyrax type maxillary expander banded on the maxillary first premolars and first molars. Mode of the expansion regimen involved two turns of the Hyrax screw for the first day, after which the Hyrax screw was activated once per day until the moment of achieving the desired expansion (1 activation = 0.25 mm). After the expansion, the device is left in the mouth for 6 months on average.

Cephalometric Evaluation

Each patient was subject to X-rays for cephalometric recording in the natural head posture (mirror position) according the method of Solow and Tallgren. [23] Measurements were performed on lateral cephalograms: six angular measurements describing cranio-cervical angulation, and five linear measurements describing airway dimension. The same procedure was repeated 6 months later.

Cephalometric points and planes used in this study are shown on Figures 1 and 2.

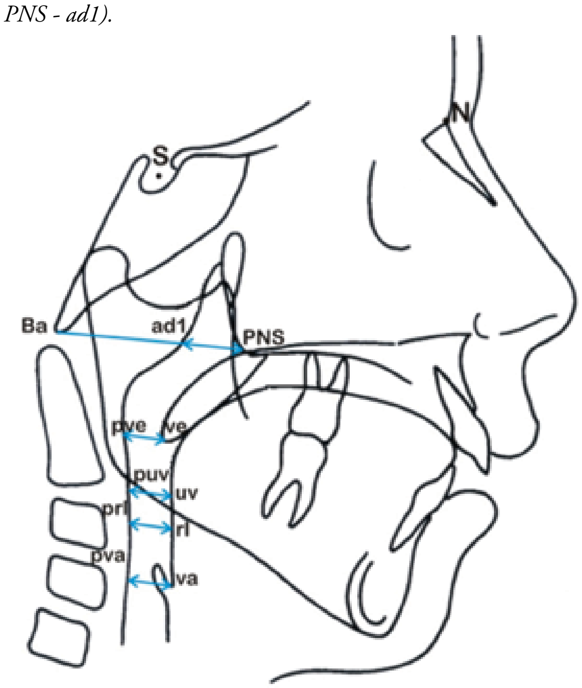
Figure 1. *Craniocervical angles (NS / OPT, FH / OPT, PP / OPT, NS / AT, FH / CVT and PP / CVT).*



The parameters that determine the craniocervical inclination

∢ NS / OPT	Angle of interaction between NS line and the tangent point of the odontoid processus cv2ip
∢ FH / OPT	Angle of interaction between state Frankfort horizontal and tangent odontoid processus
∢ PP / OPT	Angle of interaction between palatal plane and the tangent odontoid processus
∢ NS / CVT	Angle of interaction between NS line and the tangent of cervical vertebra that passes through the point cv4ip and cv2tg
∢ FH / CVT	Angle of interaction between Frankfort horizontal and tangent cervical vertebre
∢ PP / CVT	Angle interaction between palatal plane and the tangent of cervical vertebre

Figure 2. *Dimensions of pharyngeal airway (ve - pve, uv - puv, rl - prl, va - PVA, PNS - ad1).*



PNS - ad1	Distance from spina nasalis posterior to the point of ad1, located at the intersection of the line PNS - Ba and the dorsal wall of the pharynx
ve - pve	ve - velum palate, soft palate nearest point of the dorsal wall of the pharynx, pve - point dorsal pharyngeal wall closest to the point ve
uv - puv	uv - uvula, (tip of the soft palate), puv - point on the dorsal pharyngeal wall closest to the point uv
rl - prl	rl - radix linguae, point to the root of the tongue nearest the dorsal wall of the pharynx, prl - the point closest to the point rl in the dorsal wall of the pharynx
va - pva	va - vallecula epiglottis, pva - the nearest point on the dorsal wall of the pharynx to the va

All cephalograms were traced and analyzed by one researcher. Pre - and post - RME dimension comparison were made by using Student's t test, and for correlation between variables the Pearson correlation analysis was performed. All analyses were based on significant level of $P < 0.05$. The cephalometric measurements were performed twice on ten randomly selected radiographs, five from each group, in an interval of four weeks. The error of measurement was estimated by Dahlberg's formula $\sqrt{(\sum d2 / 2N)}$, where "d" is the difference between the two measurements and "N" is the number of cephalograms. The errors did not exceed 1.1 degrees for the angular measurements and 0.4 mm for the linear measurements.

RESULTS

The results obtained in cephalometric analyses are summarized in Tables 1-3. Table 1 describes the changes before and six months after RME treatment for the study group, Table 2 the changes before and six months after initial visit for control group, and Table 3 the differences between the study and the control group before and six months after the initial visit, respectively.

Table 1. *Treatment changes in craniocervical angulation and dimension of the pharynx in Group 1 (experimental). Cephalometric measurements before and six months after RME treatment*

Cranio-cervical angles	Pretreatment		Post treatment		Treatment Changes		T-value
	X	SD	X	SD	X	SD	t-test
NS/OPT	110.03	1.66	107.26	2.08	-3.77	2.40	**2.98****
FH/OPT	102.87	0.29	101.19	1.63	-1.68	0.9	**1.05***
PP/OPT	103.23	0.89	99.16	1.29	-4.07	2.15	**3.96*****
NS/CVT	112.12	4.37	108.98	2.04	-3.14	1.15	**3.98*****
FH/CVT	104.15	3.59	103.24	0.91	-0.91	2.50	**1.07***
PP/CVT	106.22	0.41	101.27	1.93	-4.95	1.05	**4.94*****
			Airway dimensions				
ve-pve	9.03	2.74	12.00	3.91	2.97	2.72	**2.63****
uv-puv	9.79	0.41	12.67	1.63	2.88	3.12	**2.88****
rl-prl	9.42	3.07	11.13	1.81	1.71	1.43	**1.69***
va-pva	14.33	3.72	16.21	4.42	1.88	3.15	**1.76***
PNS-ad1	19.62	5.33	22.14	4.37	2.52	2.50	**2.86****

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

The results show that in the investigated group treated with RME, 6 months after the first visit, there was a statistically significant decreased in craniocervical angulation, especially at the angle of interaction between palatal plane and the tangent odontoid processus (4.07 degrees, for PP/OPT angle) and angle interaction between palatal plane and the tangent of cervical vertebra (4.95

degrees for PP/CVT angle). Airway dimension in treated group increased, especially at the levels PNS-ad1 (2.52 mm), ve-pve (2.97 mm), and uv-puv (2.88 mm), respectively (Table 1).

Table 2. Treatment changes in craniocervical angulation and dimension of the pharynx in Group 2 (control). Cephalometric measurements before and six months after the initial visit

Cranio-cervical angles	Pretreatment		Post treatment		Treatment Changes		T-value
	X	SD	X	SD	X	SD	t-test
NS/OPT	110.03	1.66	112.23	2.08	2.2	0.9	**1.76***
FH/OPT	102.87	0.29	103.68	1.63	0.8	0.3	**0.55**
PP/OPT	102.51	0.21	102.51	1.29	0	0.9	**0.22**
NS/CVT	112.12	4.37	112.07	2.04	-0.5	0.9	**0.18**
FH/CVT	104.15	3.59	105.25	0.91	1.1	1.2	**0.97**
PP/CVT	104.22	0.41	106.62	1.93	1.6	1.05	**1.54***
Airway dimensions							
ve-pve	9.73	3.23	11.09	2.31	1.36	0.9	**1.29***
uv-puv	10.04	3.48	11.27	2.35	1.23	0.3	**0.89**
rl-prl	10.42	4.42	11.80	3.19	1.38	0.5	**0.87**
va-pva	14.33	3.72	16.21	4.42	1.88	0.7	**0.76**
PNS-ad1	19.09	1.42	20.44	1.87	1.35	1.2	**0.92**

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 3. Comparison between groups 6 months after the initial visit

Cranio-cervical angles	Group 1 (experimental)		Group 2 (control)		T-value
	Mean	SD	Mean	SD	t-test
NS/OPT	-3.77	2.40	2.2	0.9	**3.55*****
FH/OPT	-1.68	0.9	0.8	0.3	**2.37****
PP/OPT	-4.07	2.15	0	0.9	**3.98*****
NS/CVT	-3.14	1.15	-0.5	0.9	**3.32*****
FH/CVT	-0.91	2.50	1.1	1.2	**2.77****
PP/CVT	-4.95	1.05	1.6	1.05	**4.25*****
Airway dimensions					
ve-pve	2.97	2.72	1.36	0.9	**2.63****
uv-puv	2.88	3.12	1.23	0.3	**2.88****
rl-prl	1.71	1.43	1.38	0.5	**1.96***
va-pva	1.88	3.15	1.88	0.7	**1.15***
PNS-ad1	2.52	2.50	1.35	1.2	**2,43****

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

No significant differences were observed in the control group 6 months after the first visit, neither in craniocervical angulation nor in nasopharyngeal airway dimension (Table 2).

The comparison between groups 6 months after the first visit, shows significant changes in head posture, decreased craniocervical angulation in the study group, approximately 2.65 to 4.73 degrees for NS/OPT and NS/CVT respectively, and approximately 4.07 to 6.65 degrees for PP/OPT and PPP/CVT, respectively ($P < 0.05$; Table 3). The comparison between study group and the control group defined increased nasopharyngeal airway dimension in the study group treated with RME appliance, at the levels PNS-ad1 (1.17 mm), ve-pve (1.61 mm), and uv-puv (1.65 mm), respectively (Table 3).

DISCUSSION

The treatment outcomes associated with applied rapid maxillary expansion in the literature are mainly discussed in terms of changes in dentofacial morphology. Longitudinal studies confirmed the role of RME treatment in increasing the transverse dimensions of the maxilla, increasing the width of the nasal cavity (especially on the floor of the nose and near midpalatal suture), decreasing the nasal airway resistance and enabling normal physiological breathing. [9-14] Some investigators have reported significant changes in the position of the head and craniocervical angulation after different types of therapy that improve nasal respiratory function. [2-4] The role of the RME in changing the position of the head and reducing the craniocervical inclination was documented by certain researchers. [19-22]

The results of our study shows significant changes in the head posture and decreased craniocervical angulation six months after the RME therapy in the investigated group, especially at the angle of interaction between palatal plane and the tangent odontoid processus (PP/OPT; 4.07 degrees), and tangent of cervical vertebra (PP/CVT; 4.95 degrees), respectively (Table 1). The most important finding was that a significantly decreased craniocervical angulation approximately 2.65 to 4.73 degrees for NS/OPT and NS/CVT respectively, and approximately 4.07 to 6.65 degrees for PP/OPT and PPP/CVT, respectively was found post-treatment in the study group compared with the controls ($P < 0.05$; Table 3).

Our results are in agreement with those of longitudinal studies of Solow et al. (1984, 1996) [3,4] and Linder-Aronson (1974) [24], who have noted a reduction of craniocervical angulation of approximately 2 degrees, 2 months after completion of adenoidectomy. Also, Wenzel et al. (1983) [25] in their double blind longitudinal control study, proved that the pharmacological treatment with Budesonide improves respiratory function, which leads to a decrease in craniocervical angulation, complemented by reduced nasal resistance. Hellsing (1989) [2] found inclination of the head back to 5 degrees immediately after blockage of the nose and soon after the obstacles have been removed the head returns to its original position.

Our findings confirmed the null hypotheses, namely that applied RME treatment improves respiratory function and flexion of the head, reducing the craniocervical inclination and returning the head back to the normal position. The results of our investigation are in accordance with those of Tecco et al. (2007) [19] who noted significant decreased craniocervical angulation of approximately 5 degrees in the study group 6 mounts after the RME therapy.

The hypothesis of the existence of interaction between the position of the head, craniofacial morphology, nasorespiratory functions and the size and shape of airways were confirmed by many studies published in the literature. [3,4,17,18,20-22]

Our examination shows changes of pharyngeal airway dimensions in a study group compared with the control group, at three levels: the biggest increase of the pharyngeal airway dimension in investigated group was seen at the level of vallecula epiglottis (va-pva; 2.97 mm), at the level of uvula (uv-puv; 2.88 mm), and the level of adenoids (PNS-ad1; 2.52 mm), respectively (Table 1). Furthermore, we found improvement of the nasopharyngeal airway capacity at the investigated sample.

The comparison between the study group and the control group, defined increased nasopharyngeal airway dimension in the study group treated with the RME appliance, at the levels PNS-ad1 (1.17 mm), ve-pve (1.61 mm), and uv-puv (1.65 mm), respectively (Table 3). Our results were similar with the results in the study performed by Solow and his coworkers (1996) [4] treating the patients with obstructive sleep apnea. Our findings were also in accordance with the findings of Chang YH in his master's thesis (2011) [21] and Zhao et al. (2010) [22] for the effects of the RME on upper airways evaluated with cone-beam computed tomography.

The treatment of patients with insufficient transverse dimension of the maxillary base, due to nasopharyngeal obstruction, by applying the RME procedures delivers outstanding results, not only on dentoalveolar transversal dimensions of maxilla but also in terms of increasing the nasopharyngeal airway adequacy, changing the head posture as well as position of the mandible and tongue, creating the conditions for myofunctional balance and proper development of craniofacial complex and changing mode of respiration.

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