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Cranio-cervical posture and rapid palatal expansion therapy

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Abstract

Objective: Connections between craniocervical posture (CCP) and changes in teeth position have already been demonstrated; however, the defined pathway of relationship is still not clear. The aim of this study was to evaluate CCP modifications after rapid maxillary expansion therapy using rapid palatal expansion therapy (REP)/McNamara appliances.

Materials and Methods: A consecutive series of 35 subjects, aged between 6 and 14 years, with no prior history of orthodontic treatment, and requiring skeletal expansion of the upper arch, were selected and analyzed. All patients were treated with REP or Mcnamara appliance: the active phase of 15 days and retaining phase of 6 months. Cephalometric analysis was carried out before (T0) and after (T1) orthodontic therapy evaluating changes in the craniofacial area and those related to CCP. The obtained data were statistically analyzed for the pre-post changes.

Results: No statistically significant difference emerged indicating a modification in the CCP measured at T0 and T1 ($P > 0.05$). Patients treated with the McNamara appliance, compared to those treated with REP, showed a higher value of the angle OPT ^ Ver ($P = 0.021$), and a lower measure of the angles CVT^EVT ($P = 0.035$) and EVT^Ver ($P = 0.023$). Furthermore, patients treated with REP showed a higher hyoid angle value than those treated with McNamara ($P = 0.047$).

Conclusion: This study did not reveal any relationship between the application of palatal expansion therapy and changes in CCP.

Keywords:

Craniocervical posture, malocclusion, orthodontic therapy, rapid palatal expansion

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Introduction

Understanding the relationship between the development of craniofacial morphology, and head and neck posture is essential for the diagnosis and treatment of several morphological and functional alterations of the masticatory district and adjacent structures.[1,2]

Several studies investigated, and sometimes found, a correlation between head and neck posture and some features of the craniofacial district: the length of the mandibular body, the mandibular divergence, the length, and the angulation of the cranial base or facial growth direction.[3-4] An interesting study by Arntsen and Sonnesen reported a significant association between alterations in cervical column morphology (deviation, fusion anomalies) and skeletal overjet, large sagittal jaw relationship, retrognathia or large inclination of the jaws, and extended head posture.[3]

Craniocervical posture (CCP) was also related to several aspects or functions of the stomatognathic system: occlusion, malocclusions, parafunctions, temporomandibular dysfunctions, use of functional orthodontic devices, and patency of the upper airways.[5-7] Westersund *et al.*[5] suggested possible interconnectivity between the craniocervical junction and

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occlusal contacts. A study by An *et al.,* evaluated the craniocervical posture and the hyoid bone position in orthodontic patients with temporomandibular joint (TMJ) displacement, suggesting that these subjects present more likely an extended CCP with Class II hyperdivergent patterns.[6]

The use of orthopedic devices to correct the maxillary transverse deficiency is widely accepted and studied. Its use is related to the skeletal contraction of the upper arch, which is often associated with functional alterations such as oral breathing, finger sucking, or altered tongue posture. It was seen that the application of rapid palatal expansion therapy (RPE) determines several changes in facial morphology due to the improvements in the sagittal intermaxillary relationship, overjet and molar relation, but also due to mandibular changes with significant long-term effects.[8] Some authors hypothesized that the changes in the palatal obtained with RPE appliances can involve other bone structures such as the tongue's muscles and the suboccipital muscles.[9]

Furthermore, RPE resulted in effectively improved respiration, and some cognitive functions (i.e., concentration, cessation of nocturnal enuresis).[9-11] Ortu *et al*.[9] reported that the role of RPE in postural changes may be connected to the resulting enlargement of the pharyngeal airway space, improvement in respiratory function, and flexion of the head on the cervical column, underlying the important role that the muscular–neural network could play.[10-12]

However, special attention to the effects of rapid expansion on the posture of the head and neck is lacking, and current orthodontic literature is still unclear about the nature of this relationship.[8,9,11]

The present study aimed to investigate the relationship between CCP and RPE. The main focus was on variations related to the craniocervical angulation, the cervical lordosis, and the position of the hyoid bone, analyzing growing patients with transverse deficiency of the upper jaw, associated or not with respiratory problems.

Materials and Methods

A consecutive series of 47 patients, all spontaneously joining the Orthodontics Unit of a University hospital, from April 2, 2018, to January 30, 2019, was selected. The inclusion criteria were (1) need for orthopedic expansion of the upper arch, (2) growing age, (3) no systemic disease, (4) no congenital missing or extracted teeth before or during treatment, and (5) no previous orthodontic treatment. The exclusion criteria were (1) dental or dentoalveolar contraction of the upper arch not requiring skeletal expansion, (2) systemic disease, (3) presence of congenital or syndromic craniofacial deformities. This study was approved by the Institutional Ethics Committee (N.18-53-0000711) and informed consent was obtained from both parents of each patient.

The total patient population was thus made up of 35 subjects (11 males and 24 females) aged between 6 and 14 years (mean age: 11 years).

All subjects included in the study were Caucasian pediatric patients with potential residual growth, evaluated by the Cervical Vertebral Maturation (CVM) method, and considering stages CVM2 and CVM3.[13] In all patients, the following characteristics were evaluated: respiration (oral, nasal, mixed), deglutition (typical, atypical), and skeletal class (I, II, or III).

All patients were treated with one of the two fixed orthodontic appliances for rapid maxillary expansion generally used in our ward: *REP* (Rapid Expander of the Palate) fixed on bands on the upper first molars (20 patients) or *McNamara* appliance, built on resin splint extended from the upper first molar to the upper first premolar (15 patients). The choice of the device to be used was made on the clinical and skeletal divergence characteristics of each patient.

The activation protocol for both devices was \two activations per day for 15 days. Then, the device screw was blocked with a metallic ligation to prevent any unwanted turning back of the appliance. All patients kept the expander appliance as a restraint for the next 6 months.

To find any variations in the CCP, craniocervical angulation, and hyoid posture, all patients were asked for lateral cephalograms, before and after the expansion therapy. The radiographs were all obtained in habitual occlusion, free from intraoral devices, pre- and post-treatment, to highlight the real therapeutic effect.

Therefore, 70 lateral cephalograms (35 before and 35 after the expansive therapy) were analyzed. Cephalometric values were calculated at T0 (before treatment), and at T1 (6 months after the expansion therapy). Cephalometric measurement was performed on each cephalogram; 22 points (20 anatomical and 2 geometric projection) were found in the anatomical area of the head and neck, 14 of which were in the craniofacial area, 1 on the hyoid bone, and 7 in the cervical spine. Fifteen plans were drawn, and 15 different variables were analyzed. The skeletal class was evaluated according to the method described by Downs.[14] The cephalometric tracing was performed according to that described by Solow, for the variables related to CCP (the angle of cervical lordosis was traced according to that described by Hellsing) and craniocervical angle, and according to that described by Rocabado for the variables related to the hyoid bone posture.[15-17]

The reference points and measurements are described in Table 1 and Figure 1.

All data collected through the cephalometric study were compared and analyzed statistically, looking for a significant correlation between:

- Angle of cervical lordosis (CVT ^ EVT) and expansion therapy;
- Craniocervical angulation (SN ^ OPT, SN ^ CVT, SnaSnp ^ OPT, SnaSnp ^ CVT, ML ^ OPT, ML ^ CVT) and expansion therapy;
- Type of respiration (nasal/oral) and CCP;
- Skeletal class and craniocervical angle; and
- Type of orthodontic device (band or splint expander) and CCP.

Statistical analysis

To assess errors due to landmark identification, duplicate measurements of 10 radiographs were made.[16] The error variance was calculated using Dahlberg's formula, where d is the difference between the first and the second measurements and N is the number of double registrations. All measurements were separately realized by two expert orthodontists (E.S. and A.I.), using Dahlberg's formula to test the measurement errors, and resulting in no significant error.

To examine the differences, a Student's t-test and one-way analysis of variance (ANOVA) were used (statistically significant for $P < 0.05$). For not normally distributed data, Mann–Whitney U test was used (data normality was tested using the Shapiro–Wilk test). Statistical analysis was conducted using the SAS software (Statistical Analysis System).

Results

Epidemiological data analysis

The sample consisted of 35 subjects, mainly females, with a mean age of 10.97 years (median: 11 years; standard deviation: 10.97 years). The results concerning gender, type of respiration, deglutition, and a skeletal class of the study population are shown in Figure 2.

Pre-post expansion analysis

The measurement of the following angles, at T0 and T1, resulted in no statistically significant differences ($P > 0.05$): angle of the cervical lordosis (CVT ^ EVT); CCP (SN ^ OPT/SN ^ CVT); posture of the hyoid bone (hyoid triangle) [Table 2].

As for the relationship between CCP and type of respiration, no statistical significance resulted between the angle MGP ^ OP and the type of respiration (oral/nasal) ($P > 0.05$).

Also investigating the relationship between skeletal class and CCP, no significant relationship was found. In all different levels of skeletal classes (I, II, and III), the mean values of all variables considered showed no statistically significant differences ($P > 0.05$).

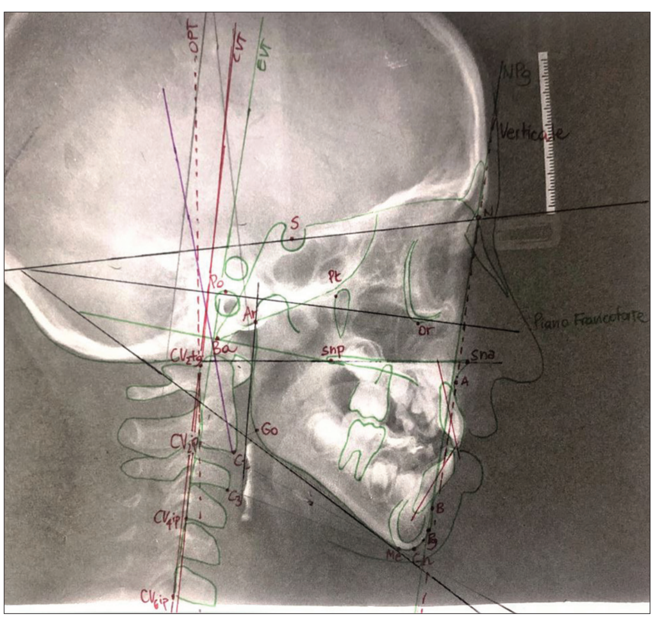

Figure 1: Planes and angles considered on the lateral cephalograms

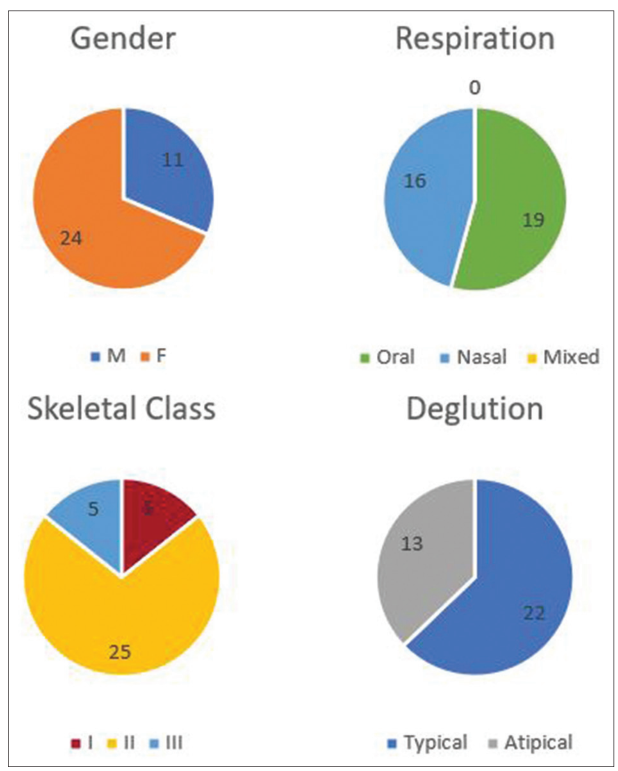

Figure 2: General characteristics of the sample

Table 1: Reference points and measurements used on the cephalometry

REFERENCE POINTS	
Skull	*• S: Sella Turcica. Middle point of the sphenoid saddle.*
	• N: Nasion. Midpoint on the sagittal plane of the fronto-nasal suture.
	• Po: Porion. Higher point of the upper margin of the external auditory canal.
	• Or: Orbit. Lower point of the lower edge of the orbit, at the conjunction of the outer orbital margin with the orbit floor.
	• Ar: Articulate. Bilateral point of intersection between the inferior border of the spheno-occipital massif and the posterior surface of the condyles. It is identified with the temporomandibular joint, where the condyle emerges from the glenoid cavity.
	• Ba: Basion. Lower midpoint of the anterior edge of the occipital foramen; on the teleradiography it corresponds to the lowest point of the basal pyramid of the occipital bone, between the anterior margin and the posterior margin.
Upper Jaw	*• A: Subspinal. Median point more retruded than the anterior concavity of the maxilla, between the anterior nasal spine and the alveolar process.*
	• Sna: Anterior nasal plug. Middle point more anterior in the sagittal plane of the anterior nasal spine.
	• Snp: Back nasal plug. Middle point more posterior of the bone palate.
	• Pt: Pterygoid. Bilateral point higher and posterior of the radiolucent area in the form of a drop, defined anteriorly by the posterior surface of the maxillary tuberosity and posteriorly by the pterygoid processes of the sphenoid.
Lower Jaw	*• B: Supramental. Midpoint of the concavity of the anterior region of the mandible, between the alveolar process and the anterior symphyseal prominence.*
	• Gn: Gnation. The median point of construction obtained by projecting the bisector of the angle formed by the facial plane and the mandibular plane onto the anterior edge of the symphysis.
	• Pg: Pogonion. Median point more prominent on the sagittal plane of the chin symphysis.
	• Me: Menton. Lower midpoint located on the lower curve of the symphysis.
	• RGN: Retrognation. The lower and posterior point of the mandibular symphysis.
	• Go. Gonion. Bilateral point of geometric construction, obtained by projecting on the mandibular angle the bisector of the angle formed by the union of two lines: one passing from the Menton to the posteroinferior margin of the mandible, the other from the Articular point to the most protruding point of the posterior margin of the branch of the jaw.
Hyoid Bone	*• H: Hyoidale. The most superior and anterior point of the body of the hyoid bone*
Cervical region	*• Cv2tg: tangent point on the OPT line to the odontoid process of the second cervical vertebra.*
	• Cv2ip: the lower and posterior point of the body of the second cervical vertebra.
	• C2: lower and anterior point of the body of the second cervical vertebra.
	• Apex: apex of the odontoid process of the second cervical vertebra.
	• C3: lower and anterior point of the body of the third cervical vertebra.
	• Cv4ip: the lower and posterior point of the body of the fourth cervical vertebra.
	• Cv6ip: the lower and posterior point of the body of the sixth cervical vertebra.
REFERENCE PLANS	
Skull	• Ver: True Vertical Line. Vertical line projected onto the film, passing through point A, perpendicular to the plane of Frankfurt.
	• SN: Cranial Plan. Horizontal plane extended between S and N.
	• FH: Frankfurt Plan. Horizontal plane extended between Po and Or.
	• NPg: Facial Plan. Vertical plane extended between N and Pg.
Upper Jaw	• SnaSnp: Bispinal Plan. Horizontal plane formed by the union of the Sna and Snp points.
Lower Jaw	• ML: Mandibular Plan. Horizontal plane led from the point Me to the inferior and posterior margin of the mandibular body.
Hyoid region	• Hyoid Triangle: obtained by drawing a straight line from C3 to RGN, one from RGN to H, and one from H to C3.
	• Hyoid Plane: the plane drawn by the point H along the major axis of the large horn of the hyoid bone.
Cervical Region	• OPT: plane tangent to the posterior surface of the odontoid process, passing through Cv2tg and Cv2ip.
	• OP: Odontoid Plan. Conducted from point C2 at the apex of the odontoid process.
	• MGP: McGregor Plan. Horizontal plane that connects the base of the occipital with the posterior nasal spine.
	• CVT: plane tangent to the posterior surface of the odontoid process, passing through Cv4ip. Defines the average portion of the cervical spine.
	• EVT: plane passing through Cv4ip and Cv6ip. Defines the lower portion of the cervical spine.
REFERENCE ANGLES	
Upper Jaw	• SNA: maxillary prognathism with respect to the cranial base.
Lower Jaw	• SNB: mandibular prognathism with respect to the cranial base.
Skeletal class	• ANB: anterior-posterior relationship between the maxilla and the mandible.
Cervical posture	• CVT ^ EVT: angle of cervical lordosis. It is given by the intersection of the CVT line, tangent after the odontoid process of the 2nd cervical vertebra and passing through the CV4ip point, with the EVT line, passing through the CV4ip and CV6ip points, which defines the lower part of the cervical spine, which physiologically presents a lordotic curvature with posterior concavity
	• OPT ^ Ver: angle of the odontoid. Tilt of the head compared to the upper cervical spine.
	• CVT ^ Ver: inclination of the average cervical spine.
	• EVT ^ Ver: inclination of the lower cervical spine.

Contd...

Table 1: Contd...

REFERENCE ANGLES	
Cranio-cervical angle	• SN ^ OPT: Cranio-cervical posture. Tilt of the head compared to the upper cervical spine. • SN ^ CVT: Cranio-cervical posture. Tilt of the head compared to the average cervical spine. • SnaSnp ^ OPT: Maxillary posture. Inclination of the maxilla with respect to the upper cervical spine. • SnaSnp ^ CVT: Maxillary posture. Inclination of the maxilla with respect to the middle cervical spine. • ML ^ OPT: Mandibular posture. Inclination of the mandible with respect to the upper cervical spine. • ML ^ CVT: Mandibular posture. Inclination of the mandible with respect to the inferior cervical spine.
Hyoid bone posture	• Angle of the hyoid plane: the upper and posterior angle given by the intersection of the hyoid plane with the plane C3-RGN. • McGregor plane angle: the upper and posterior angle given by the intersection of the odontoid plane with the McGregor plane.

Table 2: Temporal comparisons T0-T1

	T0	T1	*P*
SN^OPT	101,84±9,29	100,17±10,83	ns
SN^CVT	104,04±9,51	103,87±11,13	ns
SnaSnp^OPT	93,73±9,44	92,19±10,68	ns
SnaSnp^CVT	96,70±9,32	95,83±10,17	ns
ML^OPT	64,70±10,38	64,07±10,13	ns
ML^CVT	67,47±10,26	67,17±10,69	ns
MGP^OP	78,81±11,03	80,07±11,45	ns
CVT^EVT	12,03±8,75	12,10±6,91	ns
OPT^Ver	8,21±5,72	7,97±8,71	ns
CVT^Ver	8,50±6,24	8,39±8,37	ns
EVT^Ver	15,10±9,73	14,06±9,10	ns
HYOID ANG.	29,18±13,48	29,21±14,17	ns

Statistically significant results emerged analyzing the type of device used and the postural variations at T1 [Table 3]: patients treated with McNamara expander, compared to those treated with REP, showed a higher value of the angle OPT ^ Ver ($P = 0.021$) and lower value of the angles CVT^EVT ($P = 0.035$) and EVT^Ver ($P = 0.023$). Furthermore, patients treated with REP showed a higher hyoid angle value than those treated with McNamara ($P = 0.047$).

Discussion

This study tried to highlight the correlation between the CCP and expansion therapy of the upper jaw, investigating the differences related to the craniocervical angle, the curvature of the cervical spine, and the position of the hyoid bone, before and after the therapy, in growing patients with maxillary contraction, in combination or not with oral respiration.

The anatomical and physiological complexity of the craniofacial area requires different measurement methods to better estimate the actual modifications occurring in the craniocervical posture.[18] Although our cephalometric analysis was performed according to standardized techniques,[15-17] we believe the overlap on the radiograph of different anatomical structures, lying on different planes, and the magnification of the image, not always allowed an accurate quantification of the occurred changes.

For statistical analysis, the small sample was our main limitation, even more, evident in the evaluation of the variables CVT ^ EVT and EVT ^ Ver, because the image of the sixth vertebra was not present in all the radiographs. We expected statistically significant differences, pre- and post-treatment, of different angles values (CVT ^ EVT, SN ^ OPT, SnaSnp ^ OPT, ML ^ OPT), confirming what has already been highlighted in the literature.[11,15] A statistically significant difference was also expected for the measurements of the hyoid angle, between T0 and T1. The maxillary expansion causes a disjunction of the midpalatal suture and therefore an increase in the upper arch dimension; its indirect effect is the anterior repositioning of the mandible, finally free from the contracted jaw that was forcing it into a posterior position. This expansion also involves a change in the position of point A (an advancement on the sagittal plane and a lowering on the vertical plane), determining a mandibular post-rotation and a repositioning of the hyoid bone.[19] Looking for a relationship between the breathing (oral, nasal) of the patient at T0 and the CCP, we would expect significant values of the angle MGP ^ OP (craniocervical angle). The volumetric inadequacy of the nasal airways leads, in the oral respirator, to a repositioning of the head resulting in hyperextension; our results, however, did not show a statistically significant correlation. These results disagree with those reported in the literature that a decrease in the craniocervical angle occurs by improving the nasal respiratory function due to a hyperextension of the head.[11,20,21]

Concerning the correlation between craniocervical angles and skeletal classes, the mean values of all the considered variables showed no statistically significant differences ($P > 0.05$). This evidence disagrees with the studies affirming that subjects with II skeletal class show a hyperextension of the head, compared to those with I and III skeletal classes.[20,21]

A significant relationship between the type of device used and the postural changes to T1 was found [Table 3]. Patients treated with REP showed higher values of the hyoid angle after therapy, compared to those treated with

Table 3: Type of device used and craniocervical posture at T1

	RME.	McNamara	P
SN^OPT	93,79±10,29	96,82±19,03	Ns
SN^CVT	96,24±14,38	96,82±20,96	Ns
SnaSnp^OPT*	91,74±6,33	96,14±14,28	Ns
SnaSnp^CVT	93,83±7,34	96,75±14,42	Ns
ML^OPT	64,12±9,43	64±11,46	Ns
ML^CVT	67,64±11,03	66,46±10,53	Ns
MGP^OP	79,90±8,59	80,32±15,13	Ns
CVT^EVT	14,19±7,20	8,75±5,09	0.035
OPT^Ver	5,79±4,76	11,25±12	0.021
CVT^Ver	6,93±5,47	10,57±11,34	Ns
EVT^Ver	17,25±9,07	9,41±7,21	0.023
HYOID ANG.*	32,84±14,82	24,28±12,02	0.047

*median to IQR (interquartile range)

McNamara (P = 0.047). This result can be related to a bite opening that causes a repositioning of the mandible, which results post-rotated. As a consequence, the hyoid bone is repositioned, resulting in a higher value of the hyoid angle. Patients treated with the McNamara device reported values of the OPT ^ Ver angle (inclination of the first section of the cervical spine) higher than those treated with REP and lower values of the angles CVT^EVT (P = 0.035) and EVT^Ver (P = 0.023). These values can be explained because the hyoid bone represents the point of connection between the mandible and neck. It is closely related to the cervical spine, but also influenced by the position of the mandible as well as by the divergence, the orientation of its greater horn, and the activity of the suprahyoid and infrahyoid muscles. All these results confirm the indications in the use of McNamara or RPE appliances depending on the patient's skeletal features and divergence.

Conclusions

The results obtained from this study did not show a direct relationship between palatal expansion therapy and the CCP. The position of the hyoid bone seems to be not influenced by the therapy, but only by the type of device used. These results support the importance of considering the patient's clinical and skeletal characteristics when choosing the most appropriate type of appliance to use for palate expansion therapy. Furthermore, they underline the role of the hyoid bone as a connecting structure between the skull, cervical spine, and mandible. In this study, the improvement of the nasal respiratory function after the expansion therapy, as well as the skeletal class of the patients, resulted not directly connected to modifications of the cranial and cervical postures. Given the conflicting evidence in the literature about these correlations, further investigations are needed to deepen and better understand the influence of the palatal expansion therapy on the posture of the craniocervical area.

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Conflicts of interest

There are no conflicts of interest.

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