Cranio-cervical posture and rapid palatal expansion therapy

Emanuela Serritella¹, Alessandra Impellizzeri¹, Ludovica Musone¹, Adriana Assunta De Stefano², Galluccio Gabriella¹

Abstract

Objective: Connections between cranio-cervical 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: Cranio-cervical posture, malocclusion, orthodontic therapy, rapid palatal expansion

Introduction

Understanding the relationship between the development of craniofacial morphology, and 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]

Cranio-cervical 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.[3] suggested possible interconnectivity between the craniofacial junction and
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).[8,9,11] 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.\cite{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 $^\wedge$ EVT) and expansion therapy;
- Craniocervical angulation (SN $^\wedge$ OPT, SN $^\wedge$ CVT, SnaSnp $^\wedge$ OPT, SnaSnp $^\wedge$ CVT, ML $^\wedge$ OPT, ML $^\wedge$ 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.\cite{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 $^\wedge$ EVT); CCP (SN $^\wedge$ OPT/SN $^\wedge$ CVT); posture of the hyoid bone (hyoid triangle) \cite{Table 2}.

As for the relationship between CCP and type of respiration, no statistical significance resulted between the angle MGP $^\wedge$ 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 ($P > 0.05$).
Table 1: Reference points and measurements used on the cephalometry

| SKULL | REFERENCE POINTS |
|-------|------------------|
| Skull |                  |
| Upper Jaw | • A: Subspinal. Median point more retruded than the anterior concavity of the maxilla, between the anterior nasal spine and the alveolar process. |
| Lower Jaw | • B: Supramental. Midpoint of the concavity of the anterior region of the mandible, between the alveolar process and the anterior symphyseal prominence. |
| 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. |
| Cervical Region | • Cv2ip: the lower and posterior point of the body of the second cervical vertebra. |
| Cervical Region | • C2: lower and anterior point of the body of the second cervical vertebra. |
| Cervical Region | • Apex: apex of the odontoid process of the second cervical vertebra. |
| Cervical Region | • C3: lower and anterior point of the body of the third cervical vertebra. |
| Cervical Region | • Cv4ip: the lower and posterior point of the body of the fourth cervical vertebra. |
| Cervical Region | • Cv6ip: the lower and posterior point of the body of the sixth cervical vertebra. |

| SKULL | REFERENCE PLANS |
|-------|------------------|
| Skull | • Ver: True Vertical Line. Vertical line projected onto the film, passing through point A, perpendicular to the plane of Frankfurt. |
| Upper Jaw | • SN: Cranial Plan. Horizontal plane extended between S and N. |
| Upper Jaw | • FH: Frankfurt Plan. Horizontal plane extended between Po and Or. |
| Lower Jaw | • NPg: Facial Plan. Vertical plane extended between N and Pg. |
| Hyoid Bone | • SnSnp: Bispinal Plan. Horizontal plane formed by the union of the Sna and Snp points. |
| Cervical Region | • ML: Mandibular Plan. Horizontal plane led from the point Me to the inferior and posterior margin of the mandibular body. |
| Cervical Region | • Hyoid Triangle: obtained by drawing a straight line from C3 to RGN, one from RGN to H, and one from H to C3. |
| Cervical Region | • 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. |
| Cervical Region | • OP: Odontoid Plan. Conducted from point C2 at the apex of the odontoid process. |
| Cervical Region | • MGP: McGregor Plan. Horizontal plane that connects the base of the occipital with the posterior nasal spine. |
| Cervical Region | • CVT: plane tangent to the posterior surface of the odontoid process, passing through Cv4ip. Defines the average portion of the cervical spine. |
| Cervical Region | • EVT: plane passing through Cv4ip and Cv6ip. Defines the lower portion of the cervical spine. |

| SKULL | 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 ^ Ver: 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. |
| Cervical posture | • OPT ^ Ver: angle of the odontoid. Tilt of the head compared to the upper cervical spine. |
| Cervical posture | • CVT ^ Ver: inclination of the average cervical spine. |
| Cervical posture | • EVT ^ Ver: inclination of the lower cervical spine. |

Contd...
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 cranio cervical 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 cranio cervical posture.[19] 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 (cranio cervical 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 cranio cervical angle occurs by improving the nasal respiratory function due to a hyperextension of the head.[11,20,21]

Concerning the correlation between cranio cervical 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
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 $^\wedge$ Ver angle (inclination of the first section of the cervical spine) higher than those treated with REP and lower values of the angles CVT$^\wedge$ EVT ($P = 0.035$) and EVT$^\wedge$ 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 palatal 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 cranio-cervical area.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Akcam MO, Koklu A. Investigation of natural head posture in different head types. J Oral Sci 2004;46:15-8.
2. Romani V, Di Giorgio R, Castellano M, Barbato E, Galluccio G. Prevalence of craniofacial disorders in orthodontic pediatric population and possible interactions with anxiety and stress. Eur J Paediatr Dent 2018;19:317-23.
3. Arntsen T, Sonnesen L. Cervical vertebral column morphology related to craniofacial morphology and head posture in preorthodontic children with Class II malocclusion and horizontal maxillary overjet. Am J Orthod Dentofacial Orthop 2011;140:e1-7.
4. Castellano M, Lilli C, Barbato E, Santilli V, Galluccio G. Craniofacial asymmetry in non-syndromic orthodontic subjects: Clinical and postural evaluation. Cranio 2016;34:144-54.
5. Westerlund CD, Sholten J, Turner RJ. Relationship between craniofacial orientation and center of force of occlusion in adults. Cranio 2017;35:283-9.
6. An JS, Jeon DM, Jung WS, Yang IH, Lim WH, Ahn SJ. Influence of temporo mandibular joint disc displacement on craniofacial posture and hyoid bone position. Am J Orthod Dentofacial Orthop 2015;147:72-9.
7. Impellizzeri A, Serritella E, Putrino A, Vizzali G, Polimeni A, Galluccio G. Assessment of masticatory and cervical muscles’ thickness by ultrasonography in patients with facial asymmetry. Clin Ter 2019;170:e272-7.
8. Franchi L, Pavoni C, Faltin K Jr, McNamara JA Jr, Cozza P. Long-term skeletal and dental effects and treatment timing for functional appliances in Class II malocclusion. Angle Orthod 2013;83:334-40.
9. Ortu E, Pietropaoli D, Ortu M, Giannoni M, Monaco A. Evaluation of cervical posture following rapid maxillary expansion: A review of literature. Open Dent J 2014;8:20-7.
10. Al-Taai N, Alfatlawi F, Ransjö M, Fakhry S. Effect of rapid maxillary expansion on monosymptomatic primary nocturnal enuresis. Angle Orthod 2015;85:102-8.
11. Liu S, Xu T, Zou W. Effects of rapid maxillary expansion on the midpalatal suture: A systematic review. Eur J Orthod 2015;37:651-5.
12. McGuinness NJ, McDonald JP. Changes in natural head position observed immediately and one year after rapid maxillary expansion. Eur J Orthod 2006;28:126-34.
13. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation method: Some need for clarification. Am J Orthod Dentofacial Orthop 2003;123:19A-20A.
14. Downs WB. Variations in facial relationships; Their significance in treatment and prognosis. Am J Orthod 1948;34:812-40.
15. Solow B, Tallgren A. Head posture and craniofacial morphology. Am J Phys Anthropol 1976;44:417-35.
16. Hellesing E, McWilliam J, Reigo T, Spangfort E. The relationship between craniofacial morphology, head posture and spinal curvature in 8, 11 and 15-year-old children. Eur J Orthod 1987;9:254-64.
17. Rocabado M. Biomechanical relationship of the cranial, cervical, and hyoid regions. J Craniomandibular Pract 1983;1:61-6.
18. Yagci A, Uysal T, Usunuz S, Orhan M. Rapid maxillary expansion effects on dynamic measurement of natural head position. Angle Orthod 2011;81:850-5.
19. Carvalho FR, Lentini-Oliveira DA, Prado LB, Prado GF,
Carvalho LB. Oral appliances and functional orthopaedic appliances for obstructive sleep apnoea in children. Cochrane Database Syst Rev 2016;10:CD005520.

20. Beugre JB, Sonan NK, Beugre-Kouassi AM, Djaha K. Cranio-cervical posture and hyoid-mandibular-pharyngeal equilibrium in the presence of factors related to respiratory dysfunction. Odontostomatol Trop 2008;31:13-27.

21. Tecco S, Festa F, Tete S, Longhi V, D’Attilio M. Changes in head posture after rapid maxillary expansion in mouth-breathing girls: A controlled study. Angle Orthod 2005;75:171-6.