Cephalometric evaluation of the hyoid triangle before and after maxillary rapid expansion in patients with skeletal class II, mixed dentition, and infantile swallowing

Valeria Parisella, DDS[1]
Iole Vozza, DDS, PhD[1]
Francesca Capasso, DDS[1]
Valeria Luzzi, DDS, PhD[1]
Gaetano Ierardo, DDS, PhD[1]
Italo Nofroni, MD[2]
Antonella Polimeni, MD, DDS[1]

[1] Oral and Maxillofacial Sciences Department, Sapienza University of Rome
[2] Experimental Medicine Department, Sapienza University of Rome

Corresponding author:
Iole Vozza DDS, PhD
Oral and Maxillofacial Sciences Department
Sapienza University of Rome
Via Caserta 6
00161 Rome, Italy
Phone: +39 06 49976619
E-mail: iole.vozza@uniroma1.it

Summary
Background. **Rocabado's hyoid triangle is the only cephalometric parameter that can assess the effects of orthodontic treatment on tongue posture. *Aim.* To evaluate the restoration of tongue posture and function by conducting a cephalometric assessment of the hyoid triangle before and after rapid maxillary expansion. *Methods.* Sixty-four healthy patients aged 6-11 years with skeletal class II malocclusion, mixed dentition, and infantile swallowing took part in this study. They submitted to lateral cephalometric radiography before and after orthodontic maxillary rapid expansion, in order to assess the resulting changes in the proportions of the hyoid triangle (following Rocabado's parameters). The cephalometric findings were compared according to sex, age, and divergence using the chi-square McNemar test at the 5% significance level ($p<0.05$). *Results*. The orthodontic treatment resulted an improvement from skeletal class II malocclusion to class I, with elimination of infantile swallowing in 81.8% of male patients [95% confidence interval (CI)=61.5–92.7%], in 87.1% of patients aged 6–7 years (95% CI=71.1–94.9%). *Conclusions.* This cephalometric analysis revealed that the hyoid triangle was modified by the orthodontic maxillary expansion, reconditioning of tongue posture and function particularly among male, aged 6-7 years old with skeletal class II malocclusion, mixed dentition, and infantile swallowing.**

Key words: cephalometric evaluation, orthodontic treatment, infantile swallowing, mixed dentition, hyoid triangle.

Introduction

The tongue plays an indispensable role during all stages of embryonic development. With every act of swallowing, contact of the tongue against the palate determines the correct expansion of the latter, and its absence results in failure of the palate to form correctly, such as in Pierre Robin syndrome (1). Rocabado's hyoid triangle is the only cephalometric parameter that can be used to assess the effects of orthodontic treatment of tongue posture (2). The hyoid bone is located at the root of the tongue, and is the only bone of the human body that is not articulated with any other bone. It is located at the fourth cervical vertebra and is held in place by several muscular formations. Its position in the frontal area of the neck is divided into cranial (suprahyoid) and caudal (subhyoid) regions. The muscles of the subhyoid region generally contribute to lowering of the hyoid bone, securing it in a more caudal position than in the rest position. The suprahyoid muscles, on the other hand, allow mandible lowering (if the hyoid bone has been set caudally in advance) or raising of the hyoid bone (followed by raising of the larynx, attached to the hyoid bone) (3). This bone is indispensable for speech and chewing, and especially for jaw opening. Swallowing is another important function, involving the upper airways and digestive tract. In this situation, the mandible stabilizes itself on the maxilla, normally with a centric occlusion; the tongue exerts its force balanced between the palate and the palatal surface of the upper teeth. The tongue is a muscular complex comprising 16 smaller muscular bellies. Dynamic alterations of the tongue influence the horizontal position of the hyoid bone and its different physiological actions and synergy in both medium and long terms. The hyoid bone is the bony support of the tongue, it has 24 muscle attachments, and is related to the skull muscles (stylohyoid muscle and posterior belly of digastric muscle), the "funnel chest" (sternohyoid and sternothyroid muscles), and scapulae (omohyoid muscle). For these connections, the hyoid bone is a center of coordination that signals the brain and its related structures and allows mandibular and cervical kinematics. Monitoring of tongue position is guaranteed by anastomosis of the hypoglossal nerve with the first four cervical roots, rendering the cervical and lingual dynamics interdependent. The hyoid bone and tongue are the links between oral functions and vertebral column functions. The hyoid bone is the protagonist in the craniocervical–mandibular relationship, being connected to the skull, tongue, jaw, cervical spine, clavicle, scapula, pharynx, and larynx (4). It participates in mandibular movements that occur during swallowing, chewing, respiration, and speaking, and it responds to vertebral muscle solicitations and postural changes. The tongue is the protagonist of temporomandibular joint development and modeling of the dental arches. It has a morphogenetic role in the developmental stage because it acts as a balance in the intermediate step and as a compensator in the adult stage. At the end of tooth eruption the tongue is located at the equator of the palatal surfaces of the incisors; that is coronal to the point corresponding to the depth of the pits. In pathological situations, the tongue diverts its posture to compensate and fill the vertical, frontal, and lateral spaces. The swallowing movement is preceded by preparation of the bolus in the oral cavity. True swallowing begins once the bolus has reached the center of the dorsal surface of the tongue thanks mainly to contraction of the intrinsic lingual muscles and the styloglossus muscle. The tip of the tongue (i.e., the apex) presses against the palate in the area between the back of the retroincisive papilla and the first wrinkles of the palatine rugae (i.e., tongue position against the palate even at rest), and then movement of the tongue dorsum progressively crushes from front to back, inducing progression of the bolus toward the pharynx. The inability of the tongue to implement this action for whatever reason (e.g., anatomic problems or dysfunctional activity) impairs swallowing. Furthermore, there is a functional correlation between the tongue and the first cervical vertebrae, because tongue protrusion, retrusion, and torsion are associated with atlas protrusion, retrusion, and torsion, respectively (5). The influence of body posture on the posture of the head has been emphasized in recent decades by Rocabado, who found a frequent association between second-class occlusion, forward position of the head, decreased cervical lordosis, posterior rotation of mandible, and increased lower facial height (6, 7). A cephalometric parameter proposed by Bibby and Preston (8) and Rocabado (2) for evaluating the position of the hyoid bone from the mandible and the cervical spine, is based on a triangle constructed by joining the following anatomical points:

- H-point: the upper edge of the frontal area hyoid body;
- The retrognathic (RGN) point: the posterior-lower point of the mandibular symphysis;
- The VC3ai point: the anterior-lower point of the body of the third cervical vertebra (C3).

This triangle is assessed in a proportional and nonlinear manner and is quantifiable by the projection of H onto the VC3-RGN segment. The cephalometric position of the hyoid bone depends on the posture of the tongue, the mandible, and the spine. The triangle is positive when the bone is at the top, but lower compared to the VC3ai-RGN base, and vanishes and becomes negative during physiological swallowing in hyperdivergent patients with a back growth vector and cervical kyphosis (4). So the aim of this study was to assess the restoration of tongue posture and function by conducting a cephalometric assessment of the hyoid triangle through lateral cephalometric radiography of the skull in patients with skeletal class II malocclusion, mixed dentition, and infantile swallowing, characterized by malocclusion with sagittal and transverse discrepancies, before and after orthodontic treatment.

Materials and methods

From February 2011 to February 2012 1,152 patients presented to the Pediatric Dentistry Division, Sapienza University of Rome for an orthodontic evaluation. All patients underwent lateral cephalometric radiography in order to execute a cephalometric analysis (Planmeca Romexis®, Planmeca, Finland). The X-ray was performed in occlusion and without swallowing. For the present study, 64 healthy patients (22 males and 42 females), aged 6–11 years (mean age 7.76 years) with skeletal class II malocclusion, mixed dentition, and infantile swallowing were selected. The infantile swallowing was assessed according to the Peng method (9). According to the initial cephalometry executed during the first orthodontic visit, the patients were divided into three groups: normodivergent (group A, *n*=22), hypodivergent (group B, *n*=14), and hyperdivergent (group C, *n*=28) patients. Then it was assessed the hyoid triangle cephalometrically (following Rocabado's parameters). The triangle was drawn by joining the following points: RGN (the lowest and most posterior point of the symphysis), H (the highest and most anterior point of the hyoid bone), and VC3 (the lowest and most anterior angle of the third cervical vertebra). The cephalometric evaluation was performed by two double-blinded examiners. The hyoid triangle was classified from 1 to 5 according to the form of the obtained triangle as follows: 1=normal triangle, 2=narrow triangle, 3=elongated triangle, 4=normal inverted triangle, and 5=narrow inverted triangle (Tab. 1). The patients were subjected to orthodontic treatment with rapid maxillary expansion (RME) with an average active expansion of 15 +/- 2 days. 6.25 +/- 0.15 months after RME the patients repeated the lateral cephalometric radiography in order to assess eventual tongue posture changes (the X-ray was performed in occlusion and without swallowing).

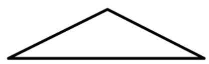
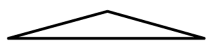
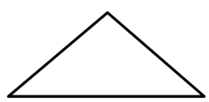
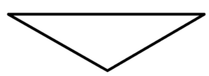
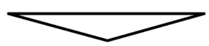
	T1: normal triangle
	T2: narrow triangle
	T3: elongated triangle
	T4: normal inverted triangle
	T5: narrow inverted triangle

Table 1. Classification of the hyoid triangle before orthodontic treatment.

The cephalometric results of the triangle before and after orthodontic treatment were compared according to sex, age, and divergence, using the chi-square McNemar test at the 5% significance level ($p<0.05$).

Results

Following orthodontic therapy with rapid maxillary expansion, 51 out of 64 subjects (79.7%) experienced successful outcomes with complete resolution of infantile deglutition, and a class I skeletal pattern was obtained. The changes in the hyoid bone triangle differed between the three groups as follows: a post-treatment turned over and/or normal triangle (group A), a reduced post-treatment turned over triangle (group B), and a reduced post-treatment triangle that was not turned over before therapy (group C). The improvement in tongue posture was remarkable for patients who were classified as having a pre-treatment T5, T3, and T2 hyoid bone triangle (Figs. 1-6).

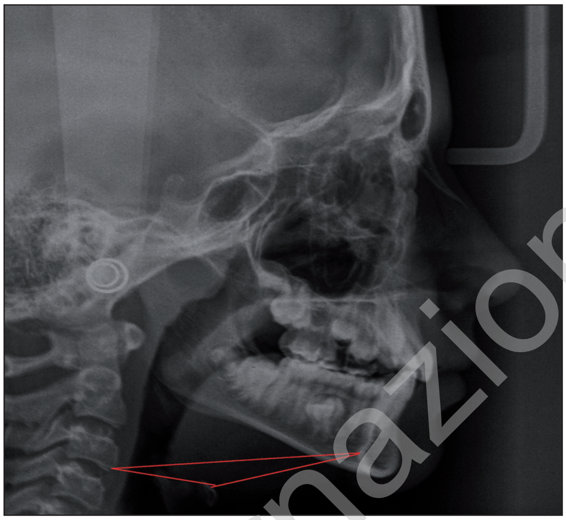


Figure 3. Normodivergent patient before therapy.

Figure 1. Hypodivergent patient before therapy.

Figure 4. Normodivergent patient after therapy.

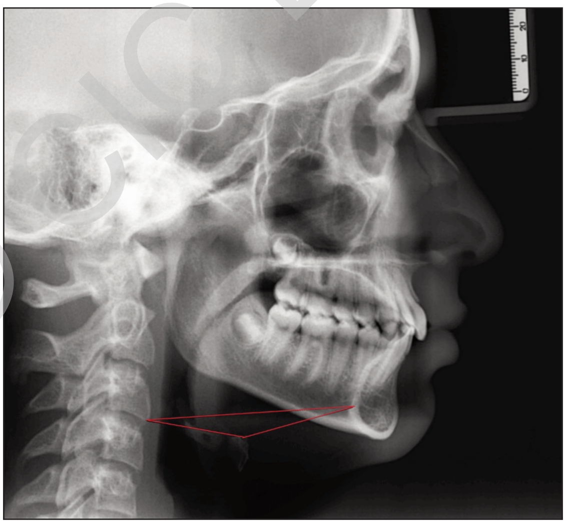


Figure 2. Hypodivergent patient after therapy.

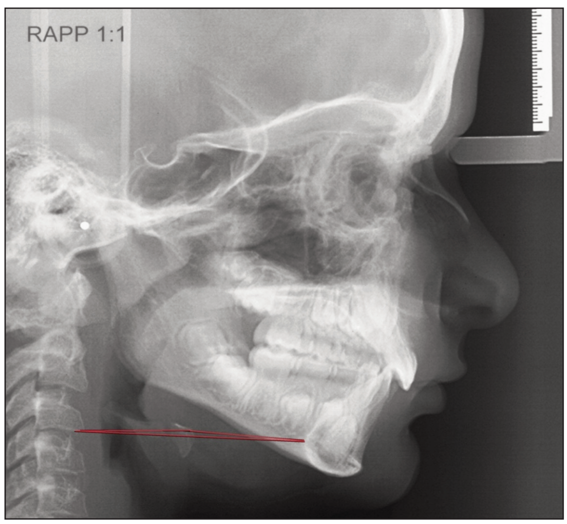


Figure 5. Hyperdivergent patient before therapy.

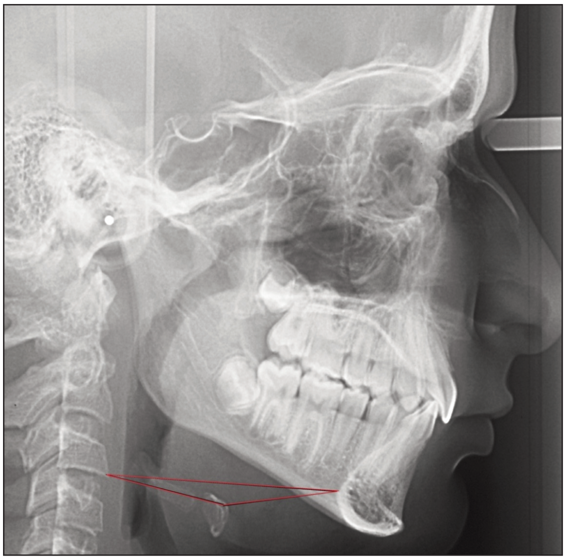


Figure 6. Hyperdivergent patient after therapy.

Out of 27 individuals with a pretreatment T5 hyoid bone triangle, 26 (96.3%) experienced a clinical improvement [95% confidence interval (CI)=81.7–99.3%], with 14 and 12 subjects obtaining a T1 and T2 hyoid bone triangles, respectively. All ten subjects (100%) classified with a pretreatment T3 hyoid bone triangle experienced a clinical improvement of their skeletal pattern class and tongue posture (95% CI=72.2–100.0%), with eight and two patients achieving a T1 and T2 hyoid bone triangle, respectively. Table 2 gives the results of the 18 patients with a pretreatment T2 hyoid bone triangle: the triangle shape changed to T1 in 15 out of 18 patients (83.3%; 95% CI=60.8–94.2%).

The success of maxillary expansion therapy differed according to age, sex, and pretreatment clinical situation of the subjects. In 18 out of 22 (81.8%) male subjects and 33 out of 42 (78.6%) female subjects, the skeletal pattern switched from class II to class I (95% CI=61.5–92.7% and 64.1–8.3%, respectively). Maxillary expansion was associated with a complete elimination of infantile deglutition and I class skeletal pattern (i.e., a desirable outcome) in 27 out of 31 (87.1%) patients aged 6-7 years (95% CI=71.1–94.9%), but in only 24 out of 33 (72.7%) patients aged ≥8 years (95% CI=55.8–84.9%). Among the 22 patients with normodivergence, 19 (86.4%) changed to a class I skeletal pattern with complete elimination of infantile deglutition (95% CI=66.7–95.3%). Following therapy, 12 out of 14 (85.7%) hypodivergent individuals had a positive clinical outcome (95% CI=60.1–96.0%). In addition, 20 out of 28 (71.4%) individuals with hyperdivergence achieved a class I skeletal pattern with complete elimination of infantile deglutition (95% CI=52.9-84.7%). The findings are summarized in Table 3.

Triangle	Number of patients before treatment	Number of patients who improved after treatment	Percentage of patients with tongue posture improvement after treatment
T2	18	15 (15T1)	83.3% (95% CI=60.8–94.2%)
T3	10	10 (8 T1–2 T2)	100% (95% CI=72.2–100%)
T5	27	26 (14 T1–12 T2)	96.3% (95% CI=81.7–99.3%)

Table 2. Percentage of patients who improved after tongue posture treatment relative to the shape of the hyoid triangle.

Patients	Number of patients before treatment	Number of patients with skeletal class I after treatment	Percentage of patients with skeletal class I and without infantile swallowing after treatment
Male	22	18	81.8% (95% CI=61.5–92.7%)
Female	42	33	78.6% (95% CI=64.1–88.3%)
Younger than 7 years	31	27	87.1% (95% CI=71.1–94.9%)
Older than 7 years	33	24	72.7% (95% CI=55.8–84.9%)
Normodivergent	22	19	86.4% (95% CI=66.7–95.3%)
Hypodivergent	14	12	85.7% (95% CI=60.1–96%)
Hyperdivergent	28	20	71.4% (95% CI=52.9–84.7%)

Table 3. Percentage of patients who improved after tongue posture treatment according to sex, age, and divergence.

Discussion

The position of the tongue at rest is considered to have a greater effect on the position of teeth than the short-term pressure of perioral soft tissues (10). It has been shown that in patients with severe maxillary constriction, the space required to accommodate the tongue close to the roof of the palate is inadequate, and tongue posture is lower than desirable (11). Because maxillary expansion may create the additional space needed to accommodate the tongue, it may be hypothesized that in patients with stable results, the tongue may be spontaneously positioning itself closer to the roof of the palate. Not only might this result in balanced cheek and tongue pressure on dentition but also in a modification of craniofacial growth and development patterns (12). After orthopedic/functional treatment to alter the jaw and improve its functional activity, we observed an increase in the space available for the correct positioning of the tongue and its posture. However, it is important to emphasize that since lingual dysfunction is difficult to intercept and correct, it is important to provide these patients with myofunctional-logopedic rehabilitation that guarantees stability of the final result achieved with the aid of orthodontic treatment (13). The cephalometric analysis of patients at the beginning of therapy revealed a reversed triangle hyoid (i.e., with the top facing upward); this indicates an incorrect tongue posture, but is a common physiological factor in hyperdivergent patients and in patients with a vertical growth tendency. However, maxillary expansion therapy successfully modified the triangle, supporting the hypothesis that palatal expansion can induce positive reconditioning of tongue posture and function (14).
Tongue posture improvement due to orthodontic maxillary expansion was achieved in all three experimental groups of patients (i.e., normo-, hypo-, and hyperdivergent), all of whom initially had skeletal class II malocclusion, mixed dentition, and infantile swallowing, as revealed using cephalometric evaluation of the hyoid triangle before and after treatment. This treatment was especially successful among male, normodivergent, or hypodivergent patients aged between 6 and 7 years. However, further studies are needed with a larger number of cases to confirm these findings.

References

1. Robin P. La Glossopatose. Doin G (Ed), Editions Semaine Dentaire, Paris, 1928.
2. Rocabado M. Biomechanical relationship of the cranial, cervical, and hyoid regions. J Craniomandibular Pract. 1983; 1(3):61-6.
3. Doual A, Léger JL, Doual JM, Hadjiat F. [The hyoid bone and vertical dimension]. Orthod Fr. 2003; 74(3):333-63.
4. Rocabado M, Iglarsh ZA. Musculoskeletal Approach to Maxillofacial Pain. J.B. Lippincott, Philadelphia, 1991.
5. Rocabado M. Diagnosis and treatment of abnormal craniocervical and cranio-mandibular mechanics. In: Solberg WK, Clarck GE (Eds). Abnormal Jaw Mechanics Diagnosis and Treatment. Quintessence, Chicago, 1984a.
6. Rocabado M. Joint distraction with a functional maxillo-mandibular orthopedic appliance. J Craniomandibular Pract. 1984;2(4):358-63.
7. Rocabado M. The importance of soft tissue mechanics in stability and instability of the cervical spine: a functional diagnosis for treatment planning. Cranio 1987;5(2):130-8.
8. Bibby RE, Preston CB. The hyoid triangle. Am J Orthod. 1981; 80(1):92-7.
9. Peng CL, Jost-Brinkmann PG, Yoshida N, Miethke RR, Lin CT. Differential diagnosis between infantile and mature swallowing with ultrasonography. Eur J Orthod. 2003; 25(5): 451-6.
10. Proffit, WR. Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthod 1978; 48:175-186.
11. Okhiba T, Hanada K. Adaptive functional changes in the swallowing pattern of the tongue following expansion of the maxillary dental arch in subjects with and without cleft palate. Cleft Palate Craniofac J 1989; 26:21-30.
12. Ricketts RM. The wisdom of the bioprogressive philosophy. Semin Orthod 1998; 4:201-209.
13. Gallerano G, Ruoppolo G, Silvestri A. Myofunctional and speech rehabilitation after orthodontic-surgical treatment of dento-maxillofacial dysgnathia. Prog Orthod. 2012 May;13(1):57-68.
14. Ozbek MM, Memikoglu UT, Altug-Atac AT, Lowe AA. Stability of maxillary expansion and tongue posture. Angle Orthod. 2009 Mar;79(2):214-20.