Hyoid Bone Position and Vertical Skeletal Pattern - Open Bite/Deep Bite

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Abstract

The Hyoid Bone (HB) is a singular bone with no articulation, but is associated with some vital functions. The purpose of this study was to test the null hypotheses that there is no change in HB position in individuals with vertical jaw dysplasia.

Methods: Eleven factors were used to determine the position of the HB. In this paper the ANOVA (two way analysis of variance) method was used to analyze the variability of the mean of each HB position according the factors facial type and gender. Comparisons with these procedures define which measurements were associated with facial type, gender; and the interactive associations between them.

Results: The HB is related with vertical facial skeletal pattern being farther from mandible and a line joining it to the third cervical vertebra in deep bite, and from posterior nasal spine and sella turcica in open bite. There is sexual dimorphism in HB position. Men have a significant lower distance to the mandible and to the vertical pterigoidea; and higher values to the third cervical vertebra, to a line joining this vertebra to mandible, to the posterior nasal spine and to the sella turcica. Also, there is an association between HB position related group and gender.

Conclusion: In this research there is a relation between the position of HB and vertical skeletal pattern. The position of the HB is more related with deep bite. There is a possibility of including the HB in the differential diagnosis of this dysplasia.

Key words: Hyoid bone, Open bite, Deep bite, Hyperdivergent facial pattern, Hypodivergent facial pattern

Introduction

The HB is the only bone that depends on the tensions of the muscles [1-4], ligaments [1-3] and fasciae [2,3] attached to it, derived from mandible [5], cranium [5], cervical spine [5] (through the cervical fasciae) [5], clavicle [5], sternum [5], elastic membranes of the larynx [5] and trachea [5]. Therefore, it indicates the tonic length of supra and infra-hyoid muscles, controlled by the central nervous system [6]. Some previous studies using various methods [7] associated the position of HB and other adjacent bones with divergent facial pattern [2], but there is no consensus on the relation of HB position and the vertical growth pattern of the face [1,7,8] and gender [9,10], probably due to the fact that their function depends on the balance of various factors. The HB controls the tongue functions if its position is normal related with the cervical column (cervical fasciae) and if the infra-hyoidal muscles have a functional relation with the scapular girdle. That depends on the unobstructed airway and a normal postural relation between head, neck and scapular girdle. According to the literature the stable hyo-cervical relation preserves the upper airway patency in adults [10], and the dysfunctional factors disturbing the HB system produce local and general effects, such as in the pelvic equilibrium [3].

The purpose of this study is to describe the position of the HB based in selected variables and a large sample size, distributed on three groups: Open Bite (OB)/hyperdivergent facial pattern, Deep Bite (DB)/hypodivergent facial pattern and a Control group with normal bite.

Materials and Methods

The study was designed taking into account that we want to evaluate the effect on the average of the measurements, considering facial type (3 levels: OB group, Control group and DB group) and gender (2 levels: male and female) as factors. The sample size determination was performed using Sample Power 3.0 of IBM® SPSS®. So considering the factors related above, and a medium effect size (f=0.25), for a significance level α=0.05 and a power of 0.85 with a number of cases per cell around 30, we need a minimum for sample size of 180 cases.

The groups were retrospectively selected based on the following inclusion criteria: negative test for dentofacial deformities and related syndromes without severe skeletal imbalances, cephalometric radiographs including C2 to C4, the presence of all dental pieces with M1, no previous orthodontic treatment, aged between 6 and 55. The resulting sample consists of 191 randomly selected individuals within each group whose lateral head films and photos were used. The sample with 94 males (49.2%) and 97 females (50.8%) were divided in three groups based on dental classification related to the functional occlusal plane: 66 normal bite (2.5 ± 1 mm), 62 OB (<0 mm) and 63 DB (>5 mm). The landmarks were done by the same investigator and the cephalogram was rotating according to the natural head position (NHP), obtained by the lateral photo, through the True Vertical Line (TVL). The NHP is related to the respiratory function, occlusion, visual function and masticatory muscles [5] and is a biologically acceptable method [11].

Horizontal (Hy/Rgn, Hy/C3, C3/Rgn, C3/PTV and Hy/PTV) and vertical (Hy/C3-Rgn, Hy/PNS and Hy/S) linear and angular (C3/Hy/S, Hy/C3/S and NaBa/CC/Hy) measurements were used to determine the HB position (*Figures 1 and 2*).

The statistical analysis was performed by the program

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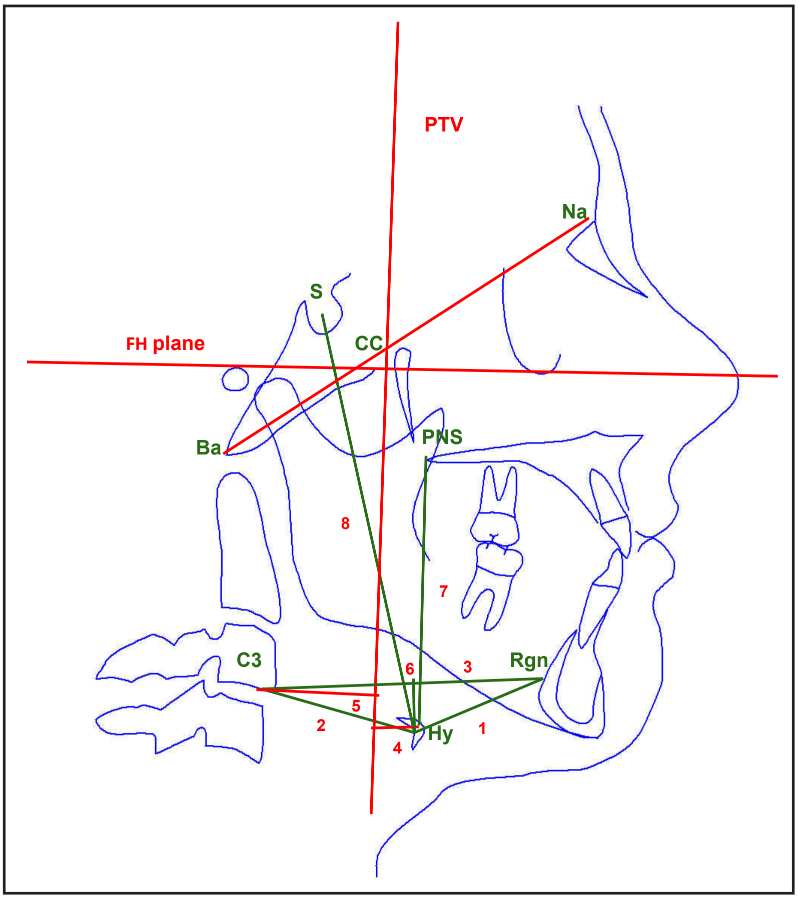

Figure 1. *Horizontal and vertical measurements of the hyoid bone position: 1,* ***Hy/Rgn****, linear distance from hyoidale to retrognation (Hy, the most anterior and superior point of the hyoid body; Rgn, the most posterior point of the mandible symphysis); 2,* ***Hy/C3****, linear distance from Hy to third cervical vertebra (C3, the point antero-inferior of the third cervical vertebra); 3,* ***C3/Rgn*** *linear distance from C3 to Rgn; 4,* ***C3/PTV****, linear distance between the C3 and vertical pterygoidea (Pt, the most posterior point of the pterygomaxillary fissure) orthogonal to Frankfurt Horizontal plane; 5,* ***Hy/PTV****, linear distance between Hy and PTV; 6,* ***Hy/C3-Rgn****, linear distance between Hy and a line joining points C3 and Rgn; 7,* ***Hy/PNS****, linear distance from Hy and posterior nasal spine; 8,* ***Hy/S****, linear distance from Hy to sella (S, midpoint of the pituitary fossa of sphenoid bone).* ***Cephalometric reference plane and line****: Frankfurt Horizontal plane (FH-plane): the horizontal plane that joins pórion and orbital; Basal plane (BaNa): the plane joining nasion and basion; Vertical pterigoidea (PTV): a line perpendicular to FH-plane at the most posterior point of the pterigomaxillary fissure.*

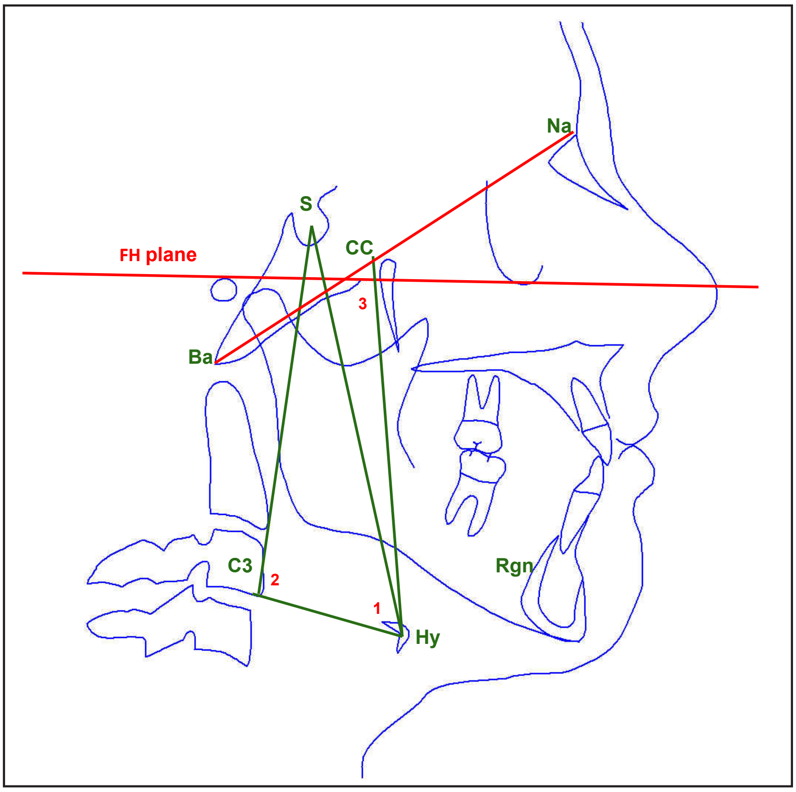

Figure 2. *Angular measurements of the hyoid bone position: 1,* ***C3/Hy/S****, angle measured from C3, Hy and Sella; 2,* ***Hy/C3/S****, angle measured from Hy, C3 and Sella; 3,* ***NaBa/CC/Hy****, angle measured between Nasion Basion plane and Center of Cranium (intersection of facial axis (Pt-Gn) and NaBa) to Hy.*

IBM® SPSS® Statistics version 20.0 for Windows® and in R version 2.13.0. The decision rule employed consisted of detecting statistical significance for a level of 0.05.

Results

Within each group we began to characterize age and gender (*Table 1*). We found that the mean age was 21.9 years for the Control group (sd=8.8 years), 22.4 years for the OB group (sd=8.3) and 21.1 years for the DB group (sd=7.9 years), and there is no statistical difference between the mean ages in the groups (F(2,190) =0.365, P=0.695).

The skeletal measurements (GoGn-SN and FMA) were taken into account within each group, since each group was selected in accordance with dental occlusion. It was found that the average GoGn-SN in the Control group was 34.36° (sd=4.79°), in the OB group 39.43° (sd=6.78°) and in the DB 30.50° (sd=5.75°). The average of FMA in the Control group was 24.14° (sd=4.54°) in the OB group was 29.04° (sd=5.73°) and in the DB group was 20.33° (sd=5.55°). The results related with skeletal measures distribution are shown in *Table 2*.

The distribution of the eleven variables of HB position, in relation to the three groups and gender are shown in *Table 3*.

Horizontal position

Statistically significant differences were detected in mean values of **Hy/Rgn** among groups (F(2,185)=3.449, p=0.034) and in relation to gender (F(1,185)=5.294,p=0.023), being the average values of Control group and males significantly lower than DB and females, respectively.

Statistically significant differences were detected in mean values of **Hy/C3** in relation to gender (F(1,185)=33.549,p≈0.000), being the average values of males significantly higher. Considering the interaction between group and gender (F (2,185)=3.694, p=0.027), the males with DB had the mean values significantly lower when compared to males of other groups, contradicting the global trend.

No statistically significant differences were detected in mean **C3/Rgn** neither in groups nor between the interaction group/gender, as in mean **C3/PTV**.

In relation to **Hy/PTV,** the males had mean values statistically lower in relation to females (F (1,185)=11.750, p=0.001). Statistically significant differences were detected in the interaction between group and gender (F (2,185)=3.806, p=0.024), the females with DB had the mean values significantly lower when compared to females of other groups, contradicting the global trend.

The profile plots for mean comparison between groups and gender for horizontal measures, with statistically significant differences, is shown in *Figure 3*.

Vertical position

Statistically significant differences were detected in mean values **Hy/C3-Rgn** between groups (F (2,185)=3.342, p=0.038) and gender (F (1,185)=10.100, p=0.002), being the average values of OB significantly lower regarding DB, as female regarding male, respectively. The multiple comparison tests between group and gender (F (2,185)=6.299, p=0.002) also allowed to verify that the females with DB had a mean Hy/C3-Rgn significantly higher when compared to males of the other groups, contradicting the global trend.

Significant differences in mean values of **Hy/PNS** and **Hy/S** between the groups (F (2,185)=3.273, p=0.040) (F (2,185)=3.837, p=0.023) and gender were found (F (1,185)=27.961, p≈0.000) (F (1,185)=57.369, p≈0.000), in the sense that the Control group and the females had significantly lower values when compared with the OB group and males, respectively. Also, in the interaction group/gender in the two measures (F (2,185)=7.199, p=0.001) (F (2,185) =12.439, p≈0.000) males with DB had a mean value significantly lower when compared to males of other groups, respectively, against the global trend. The profile plots for mean comparison between groups and gender for vertical measures, with statistically significant differences, is shown in *Figure 4*.

Angular position

Statistically significant differences in angular mean **C3/Hy/S** and **Hy/C3/S** between the genders (F(1,185)=7.395, p=0.007) (F(1,185)=5.668, p=0.018) were detected, in the sense that males had a significantly lower mean angle when compared to females. In the interaction between gender and group (F(2,185)=6.431, p=0.002) (F(2,185)=6.259, p=0.002), females with DB had a lower mean angle C3/Hy/S and a higher mean angle Hy/C3/S when compared with females of the other groups, against the global trend.

Statistically significant differences in angular mean NaBa/CC/Hy in gender (F(1,185)=5.153, p=0.024) were detected, having males a statistically significant lower mean value when compared to females.

The profile plots for mean comparison between groups and gender for angular measures, with statistically significant differences, is shown in *Figure 5*.

We also made the same comparisons against GoGn/SN and FMA (skeletal classification) to verify the results.

Table 1. *Distribution of individuals by sex.*

		Group					
		Control		Open bite		Deep bite	
		N	**%**	**N**	**%**	**N**	**%**
Sex	**F**	37	56.1%	29	46.8%	31	49.2%
	M	29	43.9%	33	53.2%	32	50.8%
	Total	66	100.0%	62	100.0%	63	100.0%
		p=0.389*		p=0.703*		p=1.00*	

no significant differences were found

Table 2. *Distribution of individuals by skeletal measures.*

		Group					
		Control		Open bite		Deep bite	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
GoGn/S	F	34.56	4.83	40.31	6.14	29.76	5.63
	M	34.10	4.82	38.66	7.30	31.21	5.87
	Total	34.36	4.79	39.43	6.78	30.50	5.75
FMA	F	24.11	5.29	29.62	5.06	19.42	5.08
	M	24.19	3.44	28.53	6.29	21.22	5.92
	Total	24.14	4.54	29.04	5.73	20.33	5.55

Table 3. Measurements of the variables.

		Group					
		Control		Open bite		Deep bite	
		Mean	Sd	Mean	Sd	Mean	Sd
Hy/Rgn	**F**	39.2	4.5	41.3	5.4	41.6	4.7
	M	38.2	7.5	37.8	4.5	40.7	5.1
	Total	38.8	6.0	39.4	5.2	41.1	4.9
Hy/C3	**F**	33.2	2.8	35.4	3.6	36.4	4.8
	M	38.6	3.9	39.4	4.6	37.8	5.6
	Total	35.6	4.3	37.5	4.6	37.1	5.2
C3/Rgn	**F**	71.5	6.3	75.3	6.4	74.3	5.8
	M	74.0	8.4	74.4	6.5	75.9	7.8
	Total	72.6	7.3	74.9	6.4	75.1	6.9
C3/PTV	**F**	36.3	6.4	37.3	7.0	34.9	6.1
	M	35.9	7.1	35.0	8.4	37.3	7.9
	Total	36.1	6.6	36.1	7.8	36.1	7.1
Hy/PTV	**F**	3.6	5.9	2.7	6.9	-.1	6.7
	M	-1.7	6.6	-2.9	8.1	.4	7.9
	Total	1.3	6.7	-.3	8.1	.2	7.3
Hy/PNS	**F**	60.4	5.5	62.5	7.0	64.4	7.7
	M	68.0	7.8	72.0	7.9	64.4	8.4
	Total	63.8	7.6	67.5	8.8	64.4	8.0
Hy/C3-Rgn	**F**	3.1	4.9	3.0	6.4	9.0	7.8
	M	8.7	5.6	7.9	6.5	7.4	6.8
	Total	5.5	5.9	5.6	6.8	8.2	7.3
Hy/S	**F**	100.1	6.4	103.7	7.7	107.6	10.0
	M	113.8	8.6	118.6	9.7	108.2	10.4
	Total	106.1	10.1	111.6	11.6	107.9	10.2
Angle C3/Hy/S	**F**	79.1	9.9	76.8	9.9	71.0	14.0
	M	70.1	9.0	69.2	10.1	74.7	11.8
	Total	75.2	10.4	72.7	10.6	72.9	12.9
Angle Hy/C3/S	**F**	82.0	10.7	83.6	10.4	89.8	14.4
	M	90.3	9.9	91.8	11.0	85.4	12.5
	Total	85.6	11.1	88.0	11.4	87.6	13.5
Angle NaBa/ CC/Hy	**F**	58.4	4.2	58.3	4.8	60.3	5.1
	M	61.5	3.7	60.2	4.4	59.7	4.3
	Total	59.8	4.2	59.3	4.6	60.0	4.7

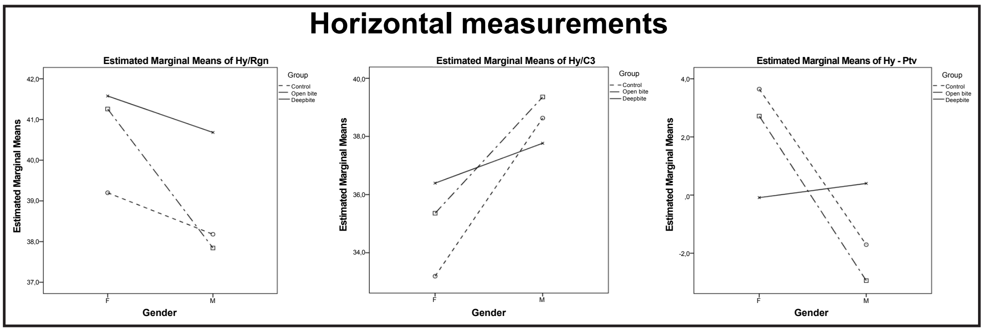

Figure 3. Profile plots for mean comparison between groups and gender for horizontal measures, with statistically significant differences.

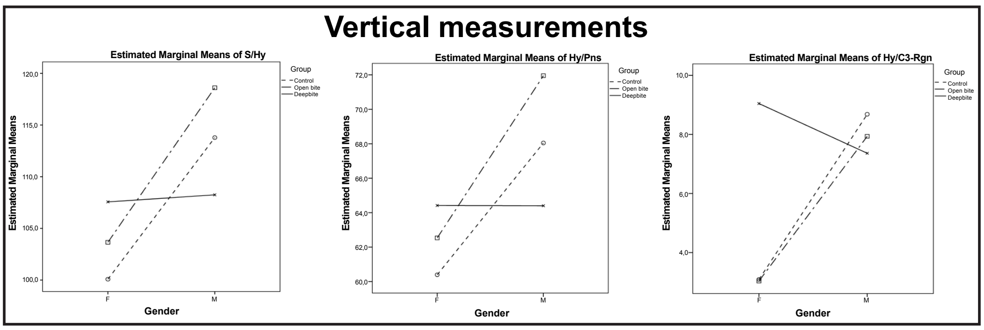

Figure 4. Profile plots for mean comparison between groups and gender for vertical measures, with statistically significant differences.

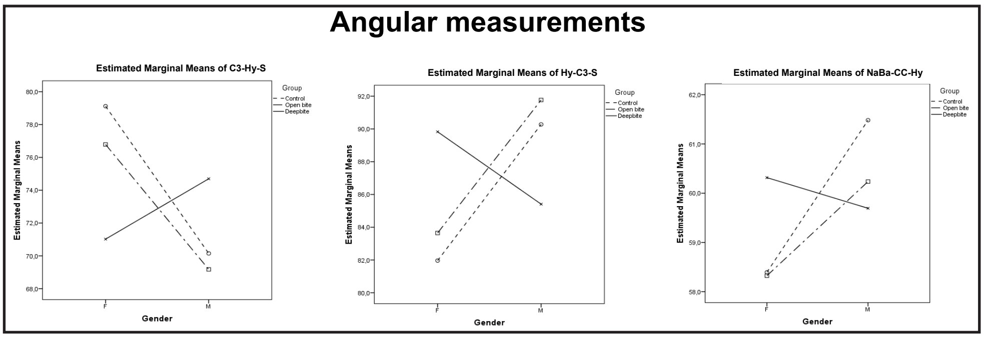

Figure 5. *Profile plots for mean comparison between groups and gender for angular measures, with statistically significant differences.*

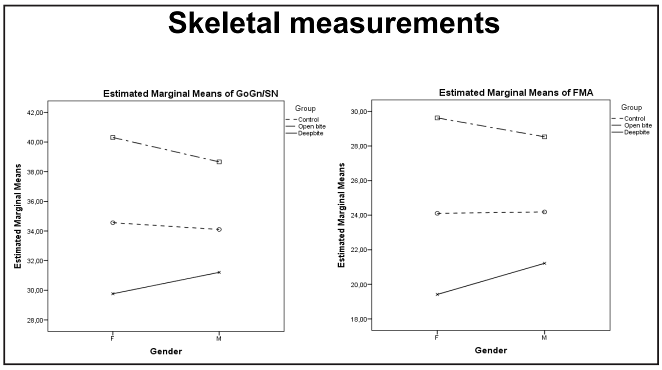

Figure 6. *Profile plots for mean comparison between groups and gender for skeletal measure, with statistically significant differences.*

Statistically significant differences were detected in mean values **GoGn/SN** and **FMA** only among groups (F(2,185) =37.482, p≈0.000) (F(2,185)=42.955, p≈0.000), respectively, in the sense that the OB group had significantly higher values when compared with the group control and DB group (*Figure 6*).

Discussion

Skeletal growth patterns are patent during early childhood (6-10 years) and usually remain stable despite the magnitude and direction of growth changes, as it has been related on the research by Bishara and Jakobsen [12] (77% of subjects maintain their facial type), among other investigators [9]. Although there is no consensus on the individual growth patterns, which can be particularly variable, the "average" growth curves for the population has apparent stability [9]. Prediction of craniofacial-growth (Ricketts – arcial method [13]; Broadbent et al. - facial templates [14]; the Johnston Gird [15]; Popovich and Thompson - cephalometric templates [16]) is based on the mean growth curve of the population, but it is particularly limited in extreme growth patterns [9]. However, the position of HB is relatively constant within the individual through growth periods [1].

The hyo-laryngeal complex descends relative to the face and cranial base but not relative to the vertebral column, during most of postnatal growth, until adulthood [10]; its descend relative to the palate and mandible is necessary for speech [8,10], and deglutition [8]. However the change of hyoid position from childhood to adulthood is not verified in this study, although the inclusion criteria cover a wide range of age, because the definitive groups had a mean age of 21.9 years for the Control group (sd=8.8 years), 22.4 years for the OB group (sd=8.3) and 21.1 years for the DB group (sd=7.9 years). At 2 years of age its position relative to cervical vertebra is achieved, with the superior margin of the hyoid body in line flowing between third (C3) and fourth (C4) cervical vertebra (Roche and Barkla [17]; Westhorpe [18]) [10]. Previous studies (Bibby and Preston [19]; Kumar et al. [20], Athanasiou et al. [21], Tallgren and Solow [22]; Haralabakis et al. [2]) demonstrated that there are few or any differences in HB position in adults with various types of malocclusion or variations in craniofacial shape. These researches differ from this study in skeletal patterns, which had statistically significant associations with the position of HB. Note that, when we mention to OB and DB, we refer the facial pattern of hyperdivergent and hypodivergent, respectively. In this study, the dental classification of the groups match the facial pattern based on GoGn/SN and FMA.

In 1963, Andersen [23] found no gender differentiation in normal and OB individuals in vertical position of HB. Subtelny and Sakuda [24] confirmed that the vertical position of the HB is related to the palate and the horizontal position of the HB associated to the lingual aspect of the mandibular symphysis. Also, Bibby and Preston [19] did not find any differences in HB position related to gender in children with a mean age of 13 years old and Angle Class I malocclusion [2]. Nevertheless Lieberman and McCarthy [10] observed sexual dimorphism in HB position relative to palatal plane and mandible during puberty. In our research, men had a more anterior and inferior position of the HB, confirmed by the measures of Hy/Rgn, Hy/C3 in horizontal plane and Hy/S, Hy/PNS and Hy/C3-Rgn in vertical plane. Thereby, the linear distances between the HB and the point S were superior in males than in females, thus confirming the anterior data that the HB was lower in males (Adamidis and Spyropoulos [25], Haralabakis et al. [2], Taylor et al. [26], Kollias and Krogstad [27]).

Tallgren and Solow [22] found out that there was a lower variability of the HB position to cervical column than to the maxilla and mandible, and the inferior position of HB was a feature of old age groups [5,28] (low position of HB and obesity are prime characteristics of obstructive sleep apnea) [8]. However, our study was not in agreement with those researchers, because there was a statistical association between the horizontal position of HB and mandible (Hy/Rgn) among groups, while according to the study of Paes et al. [8], that the HB is farther from mandible in brachyfacial subjects. In relation to the age, in our research the mean age is 21.8 years (sd=8.5 years), which does not justify the attribute of old age groups (physiological mechanisms of aging before adulthood do not exist), and it is impossible the comparisons through age because it is a transversal one.

In the study of Paes et al. [8] the HB was positioned farther from the mandibular symphysis in brachyfacial, as it occurred in our research when compared with the Control group. The same study observed that in OB and Control group, HB was more inferiorly and anteriorly positioned in relation to DB, in whose subjects there was a less variation over the time, and fewer adaptation to airway challenges [8]. Also our research agree with this one because the HB was positioned farther from the PNS and S in OB, compared with Control group, and the vertical distance to the line Rgn/C3 was lower in OB than in DB. Nerveless these findings differ from the study of Jena and Duggal [7], who demonstrated that the vertical position of HB was not affected by vertical facial growth, and the HB was more anterior in subjects with DB than in OB, when it position was evaluated with adjacent reference planes, contrary to Opdebeeck et al. [29] and Haralabakis [2].

Haralabakis [4], in their study concluded that the horizontal distance of the HB to the cervical spine, the pharynx and the mandibular point were independent from vertical discrepancies, which confirms the theory of Opdebeeck et al. [29]. They noted the same in short face syndrome (HB moves in concert with mandible, tongue, pharynx, and cervical spine). In this paper, the horizontal distance of HB to cervical spine had no relation with the vertical growth pattern as the distance to PTV. This fact may indicate that there was a functional unit to maintain the patency of the upper airway independent of vertical jaws dysplasia. However, there was a statistical association between gender and group, being the distance of Hy to C3 and to PTV lower in males with DB and in females with DB, respectively.

In this study, the measure Hy/PTV had a mean value statistically significant related to gender and in the interaction between group/gender. The males and females with DB had lower mean values (HB lies more anteriorly) than females and females of other groups, respectively, which is in accordance with the study of Jena and Duggal [9], when the reference planes were near.

This paper only describes the relations of the HB position with vertical facial pattern, sex and the relationship between both. Despite HB is the only bone of the human body without a joint, we must take it in consideration in diagnostic and prognostic of a malocclusion, because it is related to the facial divergent pattern.

The result of angular measurements of our study showed statistically significant differences in gender. The males have lower values in C3/Hy/S, Hy/C3/S and NaBa/CC/Hy.

Conclusion

As the relationship between facial pattern and HB position appears uncertain, this research was design to describe the position of the HB and other anatomical structures. Thus the purpose of this study to test the null hypothesis was not verified. The HB position is related to the gender and skeletal malocclusion, especially with DB, in whose subjects there was less variation of HB position and an increased muscular strength, in this skeletal anomaly. Longitudinal studies would be necessary to better define the relations of the skeletal facial pattern and the HB.

Competing interests

The authors declare that they have no competing interests.

References

1. Graber LW. Hyoid changes following orthopedic treatment of mandibular prognathism. *Angle Orthodontist*. 1978; **48**: 33-38.
2. Haralabakis NB, Toutountzakis NM, Yiagtzis SC. The hyoid bone position in adult individuals with open bite and normal occlusion. *European Journal of Orthodontics*. 1993; **15**: 265-271.
3. Gale A, Kilpeläinen PV, Laine-Alava MT. Hyoid bone position after surgical mandibular advancement. *European Journal of Orthodontics*. 2001; **23**: 695-701.
4. Eggensperger N, Smolka K, Johner A, Rahal A, Thüer U, Iizuka T. Long-term changes of hyoid bone and pharyngeal airway size following advancement of the mandible. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*. 2005; **99**: 404-410.
5. Marsan G. Head posture and hyoid bone position in adult turkish classe III females and males. *World Journal of Orthodontics*. 2008; **9**: 391-398.
6. Yashiro K, Takada K. Tongue muscle activity after orthodontic treatment of anterior open bite: a case report. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1999; **115**: 660-666.
7. Jena AK, Duggal R. Hyoid bone position in subjects with different vertical jaw dysplasias. *Angle Orthodontist*. 2011; **81**: 81-85.
8. Pae E, Quas C, Quas J, Garrett N. Can facial type be used to predict changes in hyoid bone position with age? A perspective based on longitudinal data. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2008; **134**: 792-797.
9. Chvatal BA, Behrents RG, Ceen RF, Buschang PH. Development and testing of multilevel models for longitudinal craniofacial growth prediction. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2005; **1281**: 45-56.
10. Lieberman DE, McCarthy RC,Hiiemae KM, Palmer JB. Ontogeny of postnatal hyoid and larynx descent in humans. *Archives of Oral Biology*. 2001; **46**: 117-128.
11. Lundström F. Registration of natural head posture in children. *Swedish Dental Journal*. 1982; **15**: 147-152.
12. Bishara SE, Jakobsen JR. Longitudinal changes in three normal facial types. *American Journal of Orthodontics.* 1985; **88**: 406-502.
13. Ricketts RM. A principle of arcial growth of the mandible. *Angle Orthodontist*. 1972; **42**: 368-386.
14. Broadbent BH Sr, Broadbent BH Jr, Golden WG. Bolton standards of dentofacial developmental growth. Saint Louis: C.V. Mosby; 1975.
15. Johnston LE. Amplified approach to prediction. *American Journal of Orthodontics*. 1975; **67**: 253-257.
16. Popovich F, Thompson GW. Craniofacial templates for orthodontic case analysis. *American Journal of Orthodontics.* 1977; **71**: 406-420.
17. Roche AF, Barkla DH. The level of the larynx during childhood. *Annals of Otology, Rhinology, and Laryngology*. 1965; **74**: 645-654.
18. Westhorpe RN. The position of the larynx in children and its relationship to the ease of intubation. *Anaesthesia and Intensive Care.* 1987; **15**: 384-388.
19. Bibby RE, Preston CB. The hyoid triangle. *American Journal of Orthodontics*. 1981; **80**: 92-97.
20. Kumar R, Sidhu SS, Kharbanda OP, Tandon DA. Hyoid bone and atlas vertebra in established mouth breathers: a cephalometric study. *Journal of Clinical Pediatric Dentistry.* 1995; **19**: 191-194.
21. Athanasiou AE, Toutountzakis N, Mavreas D, Ritzau M, Wenzel A. Alterations of hyoid bone position and pharyngeal depth and their relationship after surgical correction of mandibular

prognathism. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1991; **100**: 259-265.

22. Tallgren A, Solow B. Hyoid bone, facial morphology and head posture in adults. *European Journal of Orthodontics*. 1987; **9**: 1-8.

23. Andersen WS. The relationship of the tongue-thrust syndrome to maturation and other factos. *American Journal of Orthodontics*. 1963; **49**: 264-275.

24. Subtelny JD, Sakuda M. Open bite: Diagnosis and treatment. *American Journal of Orthodontics*. 1964; **50**: 337-358.

25. Adamidis IP, Spyropoulos MN. Hyoid bone position and orientation in Class I and Class III malocclusions. *American Journal of Orthodontics*. 1992; **101**: 308-312.

26. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. *Angle Orthodontist*. 1996; **66**: 393-400.

27. Kollias I, Krogstad O. Adult craniocervical and pharyngeal changes - a longitudinal cephalometric study between 22 and 42 years of age. Part 1: morphological craniocervical and hyoid bone changes. *European Journal of Orthodontics*. 1999; **21**: 333–344.

28. Sahin Saglam AM, Uydas NE. Relationship between head posture and hyoid position in adult females and males. *Journal of Cranio-Maxillo-Facial Surgery*. 2006; **34**: 85-92.

29. Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D. Comparative study between the SFS and LFS rotation as a possible morphogenic mechanism. *American Journal of Orthodontics*. 1978; **74**: 509-521.