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Hyoid Ratio for assessment of Hyoid bone position in skeletal Class I, II and III patients – A cephalometric study

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Abstract
Many cephalometric studies are reported in literature to study hyoid bone position in various skeletal malocclusion, but to our knowledge none has used hyoid ratio derived from hyoid triangle. Hence, this study has been undertaken to assess and compare hyoid bone position in skeletal class I, II and III using Hyoid Ratio. The aim of the present study is to investigate the antero-posterior position of hyoid bone to mandible and third cervical vertebra in class I, class II, and class III skeletal malocclusions. Hyoid bone position followed mandibular growth antero-posteriorly and its position varied with different skeletal malocclusion groups. When compared to skeletal class I group Hyoid bone is positioned closer to third cervical vertebra in skeletal class II more so in female patients and more anteriorly with skeletal class III patients. The finding of this study has got significance with reference to Oro-pharyngeal airway patency in skeletal class II malocclusions especially in female population.

Keywords: Hyoid Ratio, Hyoid Triangle, Hyoid bone, OSA, Oro-pharyngeal airway, Airway

INTRODUCTION

The hyoid bone is a slender U-shaped bone situated in the anterior midline of the neck between the mandible and the cartilage of the larynx. It is derived from the second and third pharyngeal arch cartilages. Evolution of the hyoid region is closely associated with the developmental changes in the tongue and functions like breathing, swallowing, phonation[1]. Hyoid, along with its muscle attachments, has two important functions: [a] it supports anchoring the tongue, and hence it is considered the skeleton of the tongue [b] it elevates the larynx below[2] hyoid bone is well above the symphysis in the infant. It moves well below it in the adult. As the hyoid descends during the cervical, cranial and mandible growth, its position related to these areas remains the same. The hyoid bone position is determined by the musculature attached to it and not by the occlusion[3]. Morphogenetic pattern of the head is established by the third month of postnatal life, and once attained, it does not change. By the age of two years, the first, second, and third cervical vertebrae morphology is established. In the average person at the age of three years, the hyoid bone is at the level of third and fourth cervical vertebra. It gradually descends to a level of the fourth cervical vertebra by full adulthood[4]. Hyoid is relatively stable in its relationship to the cervical vertebrae during pharyngeal growth[5]. Nasopharyngeal airway space does not undergo appreciable changes between 13 to 15 years in different skeletal patterns, but there is a decrease in oropharyngeal space[6]. The anteroposterior position of the hyoid bone depends on the relative length of the muscles running to it from the base of the cranium bilaterally and from the region of mandibular symphysis (three-point suspension). It is further modified by the pharyngeal and infrahyoid muscles and by gravity acting upon the larynx. Hyoid bone is unusual in that it articulates with no other bone, it is suspended by muscles, ligaments, and connective tissue fascia of the mandible, pharynx, skull and spine.

By all these attachments, hyoid bone is vital in many aspects, such as balancing head on the vertebral column, prevention of regurgitation of food after swallowing, in mouth opening, maintenance of stability, and maintenance of oropharyngeal airway [7–10]

The hyoid triangle was described first by Bibby Preston for the study of hyoid bone position[4]**.** Most of the studies done before his publication used cranial base references. The accuracy of the measurements used in these studies in determining the hyoid position, especially in the anteroposterior plane, may not be accurate since these landmarks can vary according to the head position. The advantage of hyoid triangle in the study of hyoid bone position is, that it is derived from the two anatomic landmarks the third cervical vertebra and the mandible, which are closer to Hyoid bone and hence less chance to have variability concerning change in head position

Previous studies have shown in class II skeletal malocclusion hyoid bone is placed closer to cervical vertebra[11] and in OSA patients, there is a decrease in the oropharyngeal space[12,13] **].** The supra hyoid musculature has been implicated as one of the major factors responsible for relapse after mandibular advancement surgery. The muscles and connective tissue comprising the suprahyoid complex must adapt to increased length brought by mandibular advancement for skeletal stability to be achieved. This can be determined by the change in hyoid bone position related to the mandible and cervical vertebra. Thus, the anteroposterior position of the hyoid bone is used to assess normal physiologic position and functions of the surrounding anatomy in this area, which is important in orthodontic and surgical relapse. And also, ever-intriguing obstructive sleep apnoea and its management maintains the interest in the study of hyoid bone. For determining the anteroposterior position of hyoid in various skeletal malocclusion, we used a ratio derived from hyoid triangle which consists of linear measurements of C3 to retro gnathion and C3 to hyoidale **(Figure 1)**. We propose the name HYOID RATIO for this. Since hyoid bone position and retrognathion are variable points, the hyoid ratio derived from the hyoid triangle will be better in determining the hyoid position than a direct linear measurement. Hence on this methodological perspective, this study can be considered as different from the other previously published studies on hyoid bone using lateral cephalogram.

MATERIALS AND METHODS

We have retrieved the pre-treatment lateral cephalogram of 100 patients in the age group of 18-30 from archives of the Department of Orthodontics, Tamil Nadu Government Dental College and Hospital. All the subjects had no positive orthodontic treatment history. For establishing control norm in the skeletal Class I, 60 cephalograms were taken which consists of 30 males and 30 females. To check the sexual dimorphism, we have taken equal number of males and females. Using hyoid triangle, a standard set of values is established for all the variables and a mean value with standard deviation is given for skeletal class I control group. After establishing a control norm, 20 subjects of skeletal Class II malocclusion and 20 subjects of skeletal Class III malocclusion were compared with that of the skeletal Class I for positional variation of the hyoid bone.

Cephalometric measurements

Lateral cephalograms was used to assess the hyoid bone position. Radiographs were taken in natural head position (NHP) for all the participants. Cephalograms were hand traced, and landmarks were identified. To determine the errors associated with radiographic measurements, 25 radiographs were randomly selected from the control group. The same person repeated the tracings and the measurements of these films two weeks after the first measurement. A paired 't' test was applied to the first and second measurements and there was no significant difference with radiographic tracings and measurements. For establishing the skeletal patterns Steiner s and Wits cephalometric analysis are used.

Assessment of hyoid bone position.

The position of the hyoid was assessed using hyoid ratio derived hyoid triangle **[AB 13]**

Volume 4, Issue 4; July-August 2021; Page No 375-385

The hyoid triangle: (Figure 1)

Hyoid triangle is formed by joining the cephalometric points retrognathion (RgN, the most inferior and posterior point on the mandibular symphysis), hyoidale (the most superior, anterior point on the body of the hyoid bone), and C3 (the most anteroinferior point on the third cervical vertebra).

Hyoid ratio:

linear measurement of C3 to RgN / linear measurement of C3 to hyoid

Statistical analysis:

The mean and standard deviation was reported for each class of malocclusion. Students' 't' test was used to calculate the difference in mean between males and females. Pearson's correlation coefficient assessed the strength of the relationship between the variables. The hyoid ratio for different groups or Classes is compared or correlated using Multiple Range Tests-- Tukey-HSD tests with significance level .050. SPSS (version 14.0) software was used for statistical analysis.

RESULTS:

We have utilized 100 cephalograms for evaluating hyoid ratio for assessment of hyoid bone position in skeletal Class I, II and III patients. Out of 100, 60 were skeletal class I, 20 were skeletal class II skeletal class III each. Of all the skeletal class I cephalograms.

Mean (SD) age of class I patients was 20.37 (2.68), 18.9 (1.57) for class II and 18 (3.95) for class III malocclusion (Table-1). Among class I malocclusion patients, the observed difference of 8.13 in mean was noted in C3-RGn between males and females and this difference was statistically significant with the p value of less than 0.001. Similarly, the observed difference of 7.33 and 2.37 were noted in C3-H and H-H respectively which was found to be statistically significant (Table-3). In class II patients, statistically significant difference in C3-H was observed between different genders with the mean difference of 3.86 (Table-4). No significant difference was seen among class III patients (Table-5).

There was a positive correlation seen between C3-RGn and C3-H, H-Rgn in class I and class III malocclusion (Table-6).

Hyoid ratio

Hyoid ratio was studied between three groups using Multiple Range Tukey – HSD test. It was almost similar in all the groups. There is statistically significant difference between skeletal class I and skeletal class II group and between skeletal class II and class III. Mean (SD) of hyoid ratio for skeletal class I, class II and class III was 2.0 ± 0.18, 1.9 ± 0.19 and 2.0 ± 0.2 respectively.

DISCUSSION

Hyoid bone position can be used to determine successful orthopedic chin cup treatment in skeletal class III malocclusions[14] **,** for prediction of surgical relapse in skeletal class II retrognathic mandible cases where advancement BSSO surgery is performed[15], prediction of changes in the soft tissue morphology following orthognathic surgery[16], growth direction of mandible and head posture[17]**,** in assessment of retained infantile swallowing.

The present study had established a control norm for Hyoid Ratio in skeletal class I subjects and compared with skeletal class II and III. Sexual dimorphism is present in this study for hyoid bone position between different skeletal malocclusion groups. These findings were in accordance with the observation made by Elham Saleh Abu Allhaija[11]**.** Significant difference was seen in the hyoid bone position with reference to third cervical vertebra in skeletal class II. Hyoid ratio was similar in different skeletal pattern which implies that in skeletal class II, hyoid is positioned posteriorly and in skeletal class III the hyoid is positioned anteriorly. But there is only statistically significant difference between class I and class II group and class II and class III groups. This implies that skeletal class II cases are more significant with reference to hyoid position[18,19].

In this study, the variable C3 – Rgn, gives the distance between third cervical vertebra and retrognathion of mandible. Its mean value is higher in males than females. This implies that the mandible length is more in male patients with skeletal class I when compared to females. There was no gender difference observed in class II and III patients.

The parameter C3 – H describes the anteroposterior position of hyoid from third cervical vertebra. The mean value for this is higher in males than in females in all the groups but, statistically significant difference noted in skeletal class I and class II. This implies that

Volume 4, Issue 4; July-August 2021; Page No 375-385

the hyoid is relatively placed closer to third cervical vertebra in females than in males and hence the oropharyngeal dimension is smaller in females than in males. This important observation is similar to the results obtained by Elham Saleh Abu Allhaija and other authors[11,18,19]**.** In skeletal class III, the mean value for C3-H was constant with minimum standard deviation, indicating that the hyoid bone position is very constant in this skeletal group for male and female subjects. This observation is similar to the study conducted by Mahesh Menon etal[20].

The variable H –RGn denotes the distance between the hyoid bone and the mandible. In class I, it was higher in males. Whereas in class II and class III, females had higher value of

H – RGn. This denoted that the hyoid is placed closer to third cervical vertebra in females than males. It must be one of the reasons for the females to develop airway obstruction than males.

H – H' denotes the vertical position of hyoid with reference to C3 and RGn plane.

And this position was varied widely from C2–C4. This has resulted in high degree of variability and standard deviation. Hence a standard set of values cannot be obtained for vertical position of hyoid for a particular skeletal group.

HPA (Hyoid Plane Angle) is the angle formed by intersection of hyoid plane and C3-RGn. There is very high variability in the values obtained in this study denoting that the hyoid bone angulation in class I, II and III groups studied vary widely. This is similar to the results obtained by Michael Stepovitch Ionnis P Adamidis and Meropi Spyropoulos [3,21]**.**

AA– PNS, which denotes the bony anteroposterior dimension of the pharynx at the level of first cervical vertebra. It is constant in each group studied and there is no gender difference and hence the anteroposterior airway dimension for all the groups is similar at this level of pharynx. The hyoid bone represents the anterior bony boundary of the pharynx at a lower level than posterior nasal spine[4,22].

There was a varying correlation coefficient values in class I (r=0.76), class II (r=0.38) and class III (r=0.49) which implies that the skeletal malocclusion might not be the only parameter determining the hyoid position[23,24]. Strong positive correlation between H – RGn and C3 – RGn was noted in all the three groups. This showed that the hyoid is placed more closer to the mandible with reference to its length and the hyoid has followed the mandible in the anterior direction during growth. The variable C3 – H and H – RGn did not correlate because of the varying anteroposterior position of hyoid and mandible.

HYOID RATIO is similar in skeletal class I, II and III with a minimal standard deviation. This implies that the hyoid bone position depends on the mandibular length. In skeletal class III, it is positioned more anteriorly and in skeletal class II, it is positioned more posteriorly as similar to the results obtained in the previous studies[18,19]. Hyoid bone has followed the mandibular growth in antero-posterior positioning more so in skeletal class II with prominent posterior position with reference to mandible especially in female subjects.

In contrast, few published studies stated that there was no difference in the hyoid bone position with reference to skeletal malocclusion and suggested that hyoid ratio might not be the only factor in determining hyoid position[23,24].

Significant difference in anteroposterior position of hyoid in skeletal class I and class II imply that hyoid is positioned more posteriorly in skeletal class II when compared to class I. Because of retro position of hyoid bone, the oropharyngeal airway must adapt to maintain proper airway. If this does not happen, there will be airway inadequacy. Airway obstruction is a major complication in severe retrognathic mandible like Pierre Robin syndrome, Treacher collin syndrome[25–27]. This study shows that even moderate retrognathic mandible has got clinical implication when it comes to adaptation of oropharyngeal airway dimension. Many previous studies have shown that most of the observed patients with OSA symptoms had mandibular retrognathism[12,13]**.** Since hyoid is positioned more posteriorly in skeletal class II, they are more prone to develop airway restriction problems. Although studies have been published with 3 D CBCT to assess the oropharyngeal airway where the position of hyoid is also assessed[28–30], Lateral cephalogram was used in this study because they are simple, less expensive, routinely taken with reduced radiation exposure compared to CBCT.

Conclusion

Hyoid ratio is obtained for skeletal class I, II and III skeletal malocclusion groups and is very similar with minimal standard deviation in all the three groups studied denoting the anteroposterior change of hyoid bone position with relation to change in mandibular position.

Hyoid bone is positioned more anteriorly in class III skeletal malocclusion subjects, and it is placed more posteriorly in class II skeletal malocclusion subjects when compared to skeletal class I group. The hyoid bone position is closer to third cervical vertebra in females than males and this is significant with reference to Oro-pharyngeal airway patency in skeletal class II malocclusions in females. Hyoid ratio can be used for future studies with reference to various surgical and orthodontic procedures since preoperative and postoperative lateral cephalogram is routinely taken.

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Volume 4, Issue 4; July-August 2021; Page No 375-385

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Table 1: Cephalometric mean and standard deviation for each group

Parameter	Class					
	Class I		Class II		Class III	
	Mean	SD	Mean	SD	Mean	SD
Age	20.37	2.68	18.95	1.57	18	3.95
C3 – RGn	75.2	7.07	68.2	5.83	81.75	7.04
C3 – H	36.67	4.86	35.3	3.25	39.9	3.88
H – RGn	39.78	4.94	34	5.25	43.05	6.13
H – H	4.68	4.5	4.9	3.19	6.1	3.32
HPA	31.28	11.24	30.85	10.86	24.9	10.91
AA – PNS	34.12	3.36	34.05	3.43	34.1	4.15

*****(distance between anterior body of atlas and posterior nasal spine)

Table 2: **Cephalometric mean and standard deviation for males and females for each group**

Gender	Parameter	Class					
		Class I		Class II		Class III	
		Mean	SD	Mean	SD	Mean	SD
Male	Age	20.93	3.32	19.67	1.75	17.07	3.43
	C3 – RGn	79.27	5.87	68	6.42	82	7.91
	C3 – H	40.33	3.33	38	3.03	40.67	3.68
	H – RGn	40.6	5.68	30.67	5.79	42.6	6.32
	H – H	5.87	5.71	4.83	1.6	6	3.25
	HPA	33.17	10.2	32.83	8.82	26.07	9.74
	AA – PNS	34.63	3.73	32	3.29	33.93	4.28
Female	Age	19.8	1.71	18.64	1.45	20.8	4.44
	C3 – RGn	71.13	5.76	68.29	5.81	81	3.94

Volume 4, Issue 4; July-August 2021; Page No 375-385

C3 – H	33	3.03	34.14	2.66	37.6	3.91
H – RGn	38.97	4.01	35.43	4.48	44.4	5.94
H – H	3.5	2.4	4.93	3.73	6.4	3.91
HPA	29.4	12.08	30	11.83	21.4	14.6
AA - PNS	33.6	2.91	34.93	3.2	34.6	4.16

Table 3: T- test for independent samples of sex: class I

Class I	Male		Female		t value	P value
	Mean	SD	Mean	SD		
C3 – RGn	79.27	5.87	71.13	5.76	5.42	<0.001*
C3 – H	40.33	3.33	33	3.03	8.93	<0.001*
H – RGn	40.6	5.68	38.97	4.01	1.29	0.2
H – H	5.87	5.71	3.5	2.4	2.09	0.04*
HPA	33.17	10.2	29.4	12.08	1.31	0.19
AA – PNS	34.63	3.73	33.6	2.91	1.2	0.24

Table 4: T- tests for independent samples of sex - class II

Class II	Male		Female		t value	P value
	Mean	SD	Mean	SD		
C3 – RGn	68	6.42	68.29	5.81	0.1	0.92
C3 – H	38	3.03	34.14	2.66	2.86	0.01*
H – RGn	30.67	5.79	35.43	4.48	2	0.06
H – H	4.83	1.6	4.93	3.73	0.06	0.09
HPA	32.83	8.82	30	11.83	0.52	0.6
AA – PNS	32	3.29	34.93	3.2	1.86	0.07

Table 5: T test for independent samples of sex – class III group

Class III	Male		Female		t value	P value
	Mean	SD	Mean	SD		
C3 – RGn	82	7.91	81	3.94	0.27	0.79
C3 – H	40.67	3.68	37.6	3.91	1.59	0.12
H – RGn	42.6	6.32	44.4	5.94	0.56	0.58
H – H	6	3.25	6.4	3.91	0.23	0.82
HPA	26.07	9.74	21.4	14.6	0.82	0.42
AA – PNS	33.93	4.28	34.6	4.16	0.3	0.77

Table 6: Pearson correlation co-efficient of different parameters in class I, class II and class III

Class I	C3-RGn	C3-H	H-RGn	HH	HPA
C3 – RGn					
C3 – H	0.76				
H – RGn	0.76	0.28			
H – H	0.18	0.42	0.24		
HPA	0.21	0.06	0.3	0.11	
AA – PNS	0.27	0.2	0.23	0.17	-0.005
Class II					
C3 – RGn					
C3 – H	0.38				
H – RGn	0.82	-0.16			
H – H	0.19	0.19	-0.11		
HPA	0.08	0.25	-0.15	0.4	
AA – PNS	0.28	-0.02	-0.22	0.28	-0.12
Class III					

C3 – RGn					
C3 – H	0.49				
H – RGn	0.79	-0.11			
H – H	-0.05	-0.29	0.24		
HPA	0.03	-0.4	0.36	0.54	
AA – PNS	0.55	0.35	0.33	-0.21	-0.41

Cephalometric points: Figure 1

C_3 – The point at the most inferior anterior position on the third cervical vertebrae RGn (retrognathion) – the most inferior posterior point on the mandibular symphysis.

H (hyoidale)– The most superior, anterior point on the body of the hyoid bone.

Hyoid plane– The plane from H along the long axis of the greater horns of the hyoid bone.

AA – The most anterior point on the body of the atlas vertebrae seen on the lateral cephalometric radiograph.

PNS (posterior nasal spine)– The tip of the posterior nasal spine seen on the lateral cephalometric radiograph.

Linear Measurements:

C_{3} –RgN- Antero posterior dimension between third cervical vertebra and mandible.

C_3 – H - Antero posterior dimension between C_3 and Hyoid.

H-RgN- Anteroposterior dimension between hyoid and mandible.

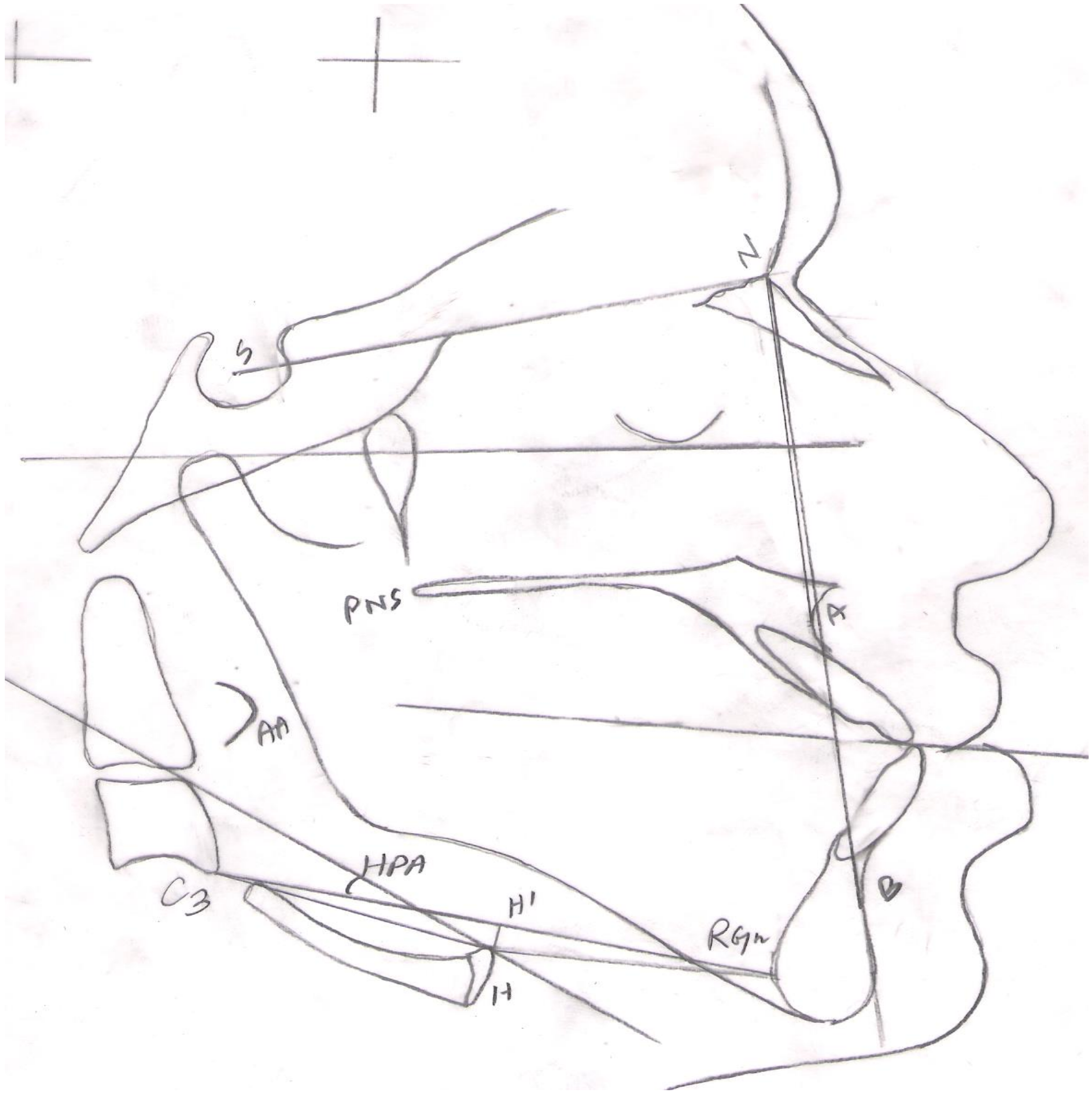
H-H^1 - Vertical dimension or position of hyoid bone with reference to C_3 and RgN plane

AA-PNS- Linear measurement between anterior bodies of atlas to posterior nasal spine

HPA – hyoid plane angle (figure 1) -Hyoid plane angle - The most superior posterior angle made by the intersection of the hyoid plane with C3-RGn.

Volume 4, Issue 4; July-August 2021; Page No 375-385

Figure 1: Hyoid triangle



Volume 4, Issue 4; July-August 2021; Page No 375-385