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**RESEARCH ARTICLE**

# A COMPARATIVE EVALUATION OF POSITION AND ORIENTATION OF HYOID BONE IN SKELETAL CLASS I, CLASS II AND CLASS III SUBJECTS: A CEPHALOMETRIC STUDY

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**ABSTRACT**

**Aims & Objectives:** 1.The purpose of this study was to compare and evaluate the positional changes of hyoid bone and its effect on the patency of airway in anteroposterior dimension of pharynx (C3 – Hy) compared with upper bony airway (AA'-PNS) in Class I, Class II and Class III malocclusions. 2. To evaluate the position of hyoid bone using hyoid triangle and its relation to mandibular position in Class I, Class II and Class III.

**Materials and methods:** Cephalometric radiographs of 75 patients (25 each of skeletal Classes I, II and III respectively) were selected from the archives of the Department of orthodontics. Radiographs were manually traced on 0.003" acetate sheets. Descriptive statistics for 14 variables were calculated.

**Results:** Linear and angular measurements showed positional alteration of hyoid bone in skeletal Class II and Class III subjects. In Class II group the hyoid bone was displaced posteriorly and angulated inferio-posteriorly. In Class III group it is positioned anteriorly and angulated superior-anteriorly. No statistically significant sexual dimorphism exists in linear and angular measurements of hyoid positioning. However, significant difference does exist in linear and angular measurements within same sex group related to skeletal Class I, Class II and Class III malocclusion.



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## INTRODUCTION

The hyoid is a horseshoe-shaped bone located high in the neck and the legs of the bone encircle the larynx just above the thyroid cartilage (Adam's apple in men) at level of the epiglottis. (Stepovich, 1965) The hyoid is divided into three parts: an unpaired middle part, the body, and the paired greater and lesser horns. (Stepovich, 1965) The muscles attached to the hyoid bone rely for their actions and have certain very important functions. The digastric muscles increase the anteroposterior dimension and the oropharynx during deglutition and the posterior belly of the digastric and the stylohyoid muscle act to prevent regurgitation of food after swallowing. (Bibby and Preston, 1981) The hyoid bone has no bony articulation but is completely suspended by muscle. It is observed that the mandible develops from the first branchial arch and the hyoid complex is identified with the second branchial arch. The anterior two-thirds arising from the first branchial arch and the posterior portion arising from the second and third branchial arches, both of these structures are closed allied with the development of the tongue. The floor of the mouth is formed by muscles, two of which are the geniohyoid and the mylohyoid. (Ruel and Bench, 1963) Brodie observed that classic analysis of the chain of muscles encircling the head includes the hyoid bone as an important part of the postural apparatus of the head and jaws and is balanced by the suprahyoid and infrahyoid musculature which is attached to the styloid process from the skull and the clavicle, thereby spanning the entire length of the neck. A close association of the hyoid bone to the cartilages of the larynx explained the importance of hyoid and tongue function to the performance of both respiration and deglutition. (Ruel and Bench, 1963) Hyoid bone position is a reflection of the relative tensions of the muscles, ligaments, and fascia attached to it and is necessary to assess normal physiologic position and functions of the surrounding anatomy in this area, which may be explainable in orthodontic and surgical relapse. (Bibby and Preston, 1981) Negus (2011) found the hyoid bone to elevate when the head was in dorsiflexion and move down when the head was in ventriflexion. Ingervall (1970) concluded a positive correlation (although not always significant) between the anteroposterior distance between retruded contact and intercuspal positions of

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the mandible and the vertical movement of the hyoid bone between these positions.

The hyoid position may be important in confirming the existence of a habit, such as tongue thrusting or mouth breathing, and therefore, proved to be a valuable diagnostic aid in preventing relapse. (Bibby, 1984) Opdebeeck and associates (Opdebeeck *et al*., 1978) concluded in subjects with short face and long face syndrome, the movement of the hyoid bone changed in harmony with movement of the mandible, tongue, pharynx, and cervical spine. Thus the positions of the hyoid bone and the tongue can be considered as indicators of pharyngeal airway passage. The hyoid bone position is constant in all three Classes while the position of the hyoid bone is determined entirely by the musculature and not by the occlusion of the teeth. (Grant, 2011) Durzo and Brodie (1962) showed that the relationship between the hyoid bone and the mandible is maintained from the age of 3 years at a level opposite to the lower portion of the third cervical vertebrae and the upper portion of the fourth cervical vertebrae. Its anteroposterior position is dependent on the relative lengths of the muscles running to it and also on gravity acting on the larynx. Bench (Ruel and Bench, 1963) observed that the hyoid bone gradually descends from a position opposite the lower half of the third and the upper half of the fourth cervical vertebrae at the age of 3 years to a position opposite the fourth cervical vertebrae in adulthood. Haralabakis *et al*. (1993) suggested that hyoid bone moves in close conjunction with the pharynx, cervical spine, and mandibular plane in patients with entirely different skeletal patterns. Erdinc *et al*. (2003) concluded that hyoid bone location in the hypodivergent group was not changed vertically. Graber (1978) strongly stated that slight variations in head position in the cephalostat, the postural position of the spine, and the state of function, all affect the position of the hyoid bone. King (1952) observed that the distance between the hyoid bone and the cervical vertebrae is constant until puberty, when the hyoid bone moves slightly forward. Since hyoid is not related to cranial reference plane (as in all previous studies) the incorrectness stem from changes in head postures is minimized as postulated by Bibby. (Bibby and Preston, 1981) Apart from establishing norms for the hyoid triangle, he found that bony pharynx at the level of PNS and hyoidale to have the same anteroposterior dimension with 0.98 coefficient of correlation and no sexual dimorphism. Current study have investigated the positioning and shift of hyoid bone and its effect on the patency of airway and also its relation to mandibular position in class I, II and III subjects.

## MATERIALS AND METHODS

A total of 75 lateral cephalometric radiographs (25 each of skeletal Classes I, II and III respectively) were systematically selected according to below mentioned inclusion criteria from the archives of orthodontic department.

**Inclusion criteria:**

1. X-rays of patient between 18-30years.
2. No history of previous orthodontic treatment.
3. Class I group: patients with Class I skeletal relationship corroborated by ANB angle value of $2^0 \pm 2^0$ (i.e $0^0$ to $4^0$) and no significant abnormalities in vertical dimension of facial form.
4. Class II group: patients with Class II skeletal relationship corroborated by ANB angle value of greater than $4^0$.
5. Class III group: patients with Class III skeletal relationship corroborated by ANB angle values $0^0$ or less than $0^0$
6. All cephalometric roentgenograms were taken in a natural head position.

**Exclusion criteria:**

1. Patients with less than 24 permanent teeth.
2. Patients suffering from craniofacial anomalies or systemic muscle or joint disorders.
3. Non-availability of good quality of pre-treatment cephalometric radiographs.

The profile radiographs were taken with the teeth in occlusion and standardized head posture. The radiographs were manually traced on 0.003inch matte acetate sheets.

The following osteometric landmarks were used in the present study (Fig. 1).

1. Nasion (N)
2. Sella (S)
3. Articulare (Ar)
4. Gonion (Go)
5. Menton (Me)
6. Capitulare (C): Center of the head of the condyle
7. Xi: Geometrically determined centroid of the ramus
8. Point D: Located by inspection as the center of body of the mandibular symphysis seen on lateral cephalogram.
9. C3: The point at the most inferior anterior position on the third cervical vertebra. (Stepovich, 1965)
10. Hyoidale (Hy): The most superior, anterior point on the body of the hyoid bone. (Stepovich, 1965)
11. AA': The most anterior point on the body of the atlas vertebra, seen on the lateral cephalogram. (Stepovich, 1965)
12. PNS
13. Subspinale (Point 'A').

For the location of point 'C', a 'template' with concentric circles on a graph was designed on the basis of geometric visualization. The circle which most nearly coincided with the perimeter of condylar head was superimposed and the geometric center of condyle was located. Similarly, for the location of 'point D', the inner cortical plate was traced and the center of this circumscribed area was located with the help of the 'template'. For the linear and angular measurements, a scale and protractor were used and readings were recorded to the nearest of 0.5 mm and half degree respectively.

**Measurements**

Following five linear and seven angular measurements were analysed for all the radiographs.

**Linear Measurements (in mm)**

1. Sella-Nasion (S-N)—it is drawn from selected point Sella to Nasion. It represents the anterior and posterior extent latent of the anterior cranial base.
2. Capitulare-Xi (C-Xi)—line connecting center of condyle, i.e. capitulare to the geometric center of the ramus of mandible, i.e. Xi. This line will be named as Capitulare axis in this study.

3. C3-Hy(C3-Hy)—formed by joining most inferior-anterior point on the third cervical vertebrae to most superior, anterior point on the hyoid bone. (Stepovich, 1965)
4. Hyoidale-Pt. D (Hy-D)—line connecting most superior anterior point on the hyoid bone to center of mandibular symphysis.
5. AA'-PNS—line adjoining the most anterior point on body of atlas vertebrae and posterior nasal spine designating upper bony nasopharynx. (Stepovich, 1965)

**Angular Measurements (in degree)**

1. Saddle angle (NSAr)—the angle formed by joining Nasion, Sella and Articulare is an assessment of the relationship of anterior and posteriolateral cranial base.
2. Articulare angle (SArGo)—the angle is constructed by joining sella, articulare and gonion.
3. Gonial angle (ArGoMe)—the angle formed by tangents of body of the mandible and posterior border or ramus.
4. SNA—the angle formed with sella nasion plane and the line joining nasion and point A.
5. SND—the angle formed between sella-nasion plane and nasion-point D plane.
6. Hyoidale angle (C3HyD)—the angle formed by C3 to Hyoidale plane and Hyoidale Pt. D. The angle formed superiorly by two planes is read as hyoidale angle.
7. Hyoid plane angle—formed by intersection of long axis of greater horn of hyoid with C3-Pt. D line.

## RESULTS

The data obtained by the linear and angular measurements from tracings of lateral cephalograms was subjected to statistical analysis. The arithmetic means and standard deviations of the linear and angular measurements are calculated. In linear parameters, a significant difference was observed in HyD (p=0.002), $C_3D$ (p=0.002) and AA'-PNS (p=0.034) on comparing Class I, Class II and Class III groups (Table 1) indicating posterior displacement of hyoid bone in Class II group and anterior displacement of hyoid bone in Class III group compared to Class I group.

**Table 1. Comparison between Class I, II, III – Linear Measurement**

| | Class | N | Mean | SD | 'f' value | 'p' value |
|---|---|---|---|---|---|---|
| C3 Hy | Class 1 | 25 | 36.16 | 4.964 | 0.421 | 0.658 |
| | Class 2 | 25 | 35.68 | 3.648 | | |
| | Class 3 | 25 | 36.80 | 4.282 | | |
| AA'- PNS | Class 1 | 25 | 33.28 | 5.029 | 3.535 | 0.034 |
| | Class 2 | 25 | 33.56 | 3.150 | | |
| | Class 3 | 25 | 30.80 | 3.708 | | |
| SN | Class 1 | 25 | 71.12 | 4.737 | 0.991 | 0.376 |
| | Class 2 | 25 | 71.88 | 3.700 | | |
| | Class 3 | 25 | 70.36 | 2.752 | | |
| C-Xi | Class 1 | 25 | 32.16 | 4.488 | 1.682 | 0.193 |
| | Class 2 | 25 | 31.76 | 2.454 | | |
| | Class 3 | 25 | 33.64 | 4.192 | | |
| C3Hy: HyD | Class 1 | 25 | .8848 | .21054 | 2.871 | 0.063 |
| | Class 2 | 25 | .8360 | .14773 | | |
| | Class 3 | 25 | .7776 | .09545 | | |
| HyD | Class 1 | 25 | 41.80 | 6.238 | 6.699 | 0.002 |
| | Class 2 | 25 | 43.16 | 5.490 | | |
| | Class 3 | 25 | 47.56 | 5.694 | | |
| C3D | Class 1 | 25 | 77.64 | 6.217 | 6.961 | 0.002 |
| | Class 2 | 25 | 76.96 | 6.937 | | |
| | Class 3 | 25 | 83.64 | 7.670 | | |

**Table 2. Comparison between Class I, II, III –Angular measurement**

| | Class | N | Mean | SD | 'f' value | 'p' value |
|---|---|---|---|---|---|---|
| C3HyD | Class 1 | 25 | 162.20 | 3.594 | 125.053 | 0.000 |
| | Class 2 | 25 | 150.76 | 5.797 | | |
| | Class 3 | 25 | 169.52 | 2.663 | | |
| SNA | Class 1 | 25 | 82.00 | 3.403 | 0.187 | 0.830 |
| | Class 2 | 25 | 82.52 | 2.946 | | |
| | Class 3 | 25 | 81.80 | 5.937 | | |
| SND | Class 1 | 25 | 77.32 | 4.130 | 33.895 | 0.000 |
| | Class 2 | 25 | 74.16 | 3.051 | | |
| | Class 3 | 25 | 83.72 | 5.111 | | |
| NSAr | Class 1 | 25 | 126.60 | 5.838 | 6.271 | 0.003 |
| | Class 2 | 25 | 128.68 | 5.406 | | |
| | Class 3 | 25 | 122.44 | 7.578 | | |
| SArGo | Class 1 | 25 | 140.08 | 4.645 | 6.133 | 0.003 |
| | Class 2 | 25 | 135.12 | 6.797 | | |
| | Class 3 | 25 | 139.12 | 4.106 | | |
| ArGoMe | Class 1 | 25 | 126.40 | 5.824 | 0.102 | 0.903 |
| | Class 2 | 25 | 126.48 | 5.229 | | |
| | Class 3 | 25 | 127.08 | 6.324 | | |
| Hyoid plane angle | Class 1 | 25 | 12.36 | 2.782 | 76.103 | 0.000 |
| | Class 2 | 25 | 17.40 | 3.014 | | |
| | Class 3 | 25 | 7.00 | 3.136 | | |

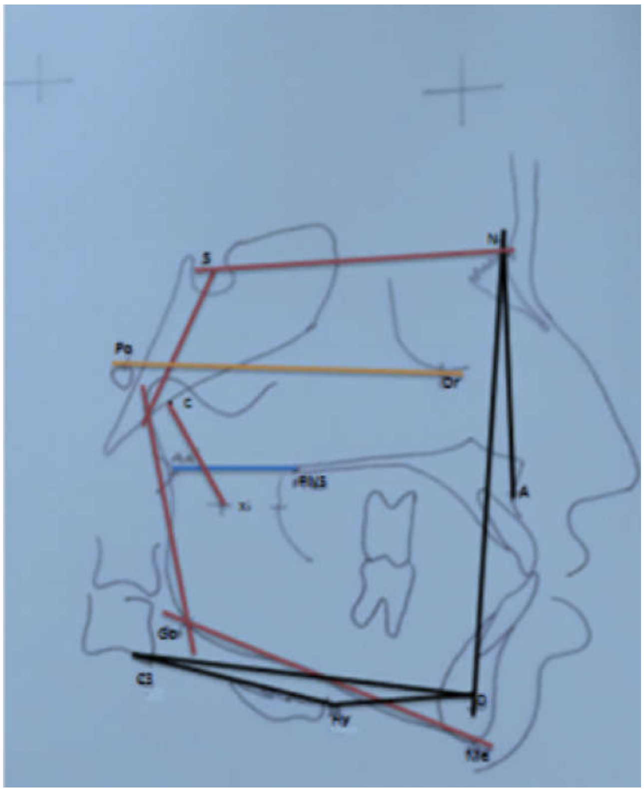

**Fig. 1. Osteometric landmarks**

In angular parameters, a highly significant difference (p=0.000) was observed in hyoidale angle ($C_3HyD$), Hyoid plane angle, SND, NSAr and SArGo on comparing Class I, Class II and Class III groups (Table 2) indicating posteroinferior positioning of hyoid bone in Class II group and anterosuperior positioning of hyoid bone in Class III group compared to Class I group.

## DISCUSSION

This study analyses the hyoid bone position using "hyoid triangle" and relates the hyoid bone to the cervical vertebrae and the mandible.

**Table 3. Coefficient of correlation 'r' of angle C3-HyD with following angular measurements**

| Group | Gender | | SNA | SND | NSAr | SArGo | ArGoMe | Hyoid plane angle |
|---|---|---|---|---|---|---|---|---|
| Class 1 | Male | r | -0.275 | -0.458 | 0.386 | -0.300 | -0.166 | -0.333 |
| | | 'p' value | 0.413 | 0.157 | 0.241 | 0.370 | 0.627 | 0.318 |
| | Female | r | -0.559 | -0.457 | 0.461 | 0.118 | -0.673 | 0.231 |
| | | 'p' value | 0.038 | 0.100 | 0.097 | 0.687 | 0.008 | 0.426 |
| Class 2 | Male | r | -0.239 | -0.203 | 0.607 | -0.728 | 0.044 | -0.502 |
| | | 'p' value | 0.478 | 0.550 | 0.048 | 0.011 | 0.899 | 0.116 |
| | Female | r | -0.332 | -0.293 | 0.061 | -0.085 | 0.231 | -0.690 |
| | | 'p' value | 0.246 | 0.310 | 0.837 | 0.773 | 0.427 | 0.006 |
| Class 3 | Male | r | 0.231 | 0.135 | 0.050 | -0.032 | 0.040 | -0.841 |
| | | 'p' value | 0.427 | 0.644 | 0.864 | 0.913 | 0.893 | <0.001 |
| | Female | r | -0.501 | -0.542 | 0.339 | 0.033 | -0.040 | -0.639 |
| | | 'p' value | 0.117 | 0.085 | 0.307 | 0.923 | 0.908 | 0.034 |

Since the mandibular symphysis is at a level more comparable to the axis of rotation of the head than the cranium, the effect of head movement will be minimized and thus the hyoid position can be determined more correctly. (Bibby and Preston, 1981) This discussion focuses mainly on the variations in mandibular morphology and concurrent changes in associated structures in skeletal Class I, Class II and Class III subjects. It was found that the positioning of hyoid was variable in skeletal Class I, Class II and Class III malocclusion. The shift of hyoid and its effect on the patency of airway, the anteroposterior dimension of pharynx (C3-Hy) was also compared with upper bony airway (AA'- PNS) in skeletal Class I, Class II and Class III malocclusion. It was observed that the difference in values establishes that, change exists in anteroposterior dimension of C3-Hy in Class I to Class II to Class III but no statistical significant difference was seen. A slight decrease (statistically not significant) in anteroposterior dimension of pharynx at level of hyoid in Class II samples compared to Class I and Class III was seen. This may be due to the posterior movement of hyoid bone as mandible attains distal position in Class II sample since, the patency of the airway is to be maintained for the survival, and hence the further posterior displacement of hyoid was resisted in Class II samples. A significant difference was observed in $C_3D$ on comparing Class I, Class II and Class III groups. The distance between cervical vertebrae and mandibular symphysis ($C_3$-D) was significantly decreased in samples with Class II malocclusion compared to Class I malocclusion. The same results were observed in a study by Rohit Khanna *et al*. (2011) The probable reason for posterior displacement of hyoid and slight decrease in C3-Hy dimension position of hyoid may be to accommodate the muscles geniohyoid and anterior belly of diagastric. The decrease in C3-Hy was not sufficient to accommodate the hyoid and hence the change was expected in either superior or inferior direction. Similarly, the distance between cervical vertebrae and mandibular symphysis (C3-D) was significantly increased in samples with Class III malocclusion compared to Class I. The probable reason for anterior displacement of hyoid and slight increase in C3-Hy dimension position of hyoid was due to the muscles geniohyoid and anterior belly of digastrics being stretched as the mandible move forward. The increase in C3-Hy was not sufficient to accommodate the hyoid and hence the change was expected in superior direction compared to Class I malocclusion.

A significant difference was observed in AA'-PNS on comparing Class I, Class II and Class III groups. It showed a highly significant difference in hyoidale angle ($C_3$HyD) on comparing Class I, Class II and Class III groups. It was found that retrognathic mandible leads to inferoposterior displacement of hyoid bone and prognathic mandible leads to superior-anterior displacement of hyoid bone. This inferior-posterior displacement of hyoid might affect the tongue posture in oral cavity and stretching of the pharyngeal wall, because hyoglossus muscles and middle constrictor muscles of pharynx take their attachments on greater horn of hyoid bone. This result is in accordance with Rohit Khanna *et al*. (Durzo and Brodie, 1962) Grant (Bibby, 1984) also concluded the difference in hyoid bone position, and found hyoid bone was higher in Class III than in Class II subjects in relation to cervical vertebrae. In a study by Adamidis and Spyropoulos (1992) a statistically significant difference in the position and inclination of the hyoid bone in the two groups (Class I and Class III) was found. The hyoidale angle was also correlated to angle SNA (Table 3) which showed no statistically significant difference in Class I normal, Class II and Class III samples in both males and females. The above findings explained that Class II tendency of samples in the present study was due to mandibular retrusion rather than maxillary procumbency and Class III tendency of samples in the present study was due to mandibular protrusion rather than maxillary retrusion. It was thus interpreted that for change in position of hyoid it was necessary that the subjects should possess retrognathic or prognathic mandible. A highly significant difference was observed in hyoid plane angle on comparing Class I, Class II and Class III groups. The hyoid plane angle (long axis of greater horn of hyoid to C3-D line) when correlated with hyoidale angle (C3HyD) revealed a highly significant negative coefficient of correlation. The increase in hyoid plane angle with an inferior drop of body of hyoid in Class II malocclusion was noticed, thereby maintaining the relative length of middle constrictor muscle of pharynx and hyoglossus muscle, which takes its attachments on greater horn of the hyoid bone which is in accordance with Rohit Khanna *et al*. (Durzo and Brodie, 1962) However, the decrease in hyoidale angle was to accommodate geniohyoid, anterior belly of diagastric and mylohyoid muscles. The slight posterior displacement is justifiable due to stylohyoid muscle and ligaments attached to the body of hyoid, which pulls the hyoid bone posteriorly when it is displaced inferiorly, encroaching upon pharyngeal space in Class II subjects, resulting the decrease in anteroposterior dimension of pharyngeal space. (Durzo and Brodie, 1962) In the current study, the decrease in hyoid plane angle with a superior positioning of body of hyoid in Class III malocclusion was noticed. The hyoid bone moved closer to the body of the mandible after surgical mandibular advancement, which may be due to stretching of the hyoid muscles, as the active and balancing forces of the supra- and infra-hyoid muscles determine the hyoid bone position as concluded by Gale *et al*. (2001) Sao Paulo (Sao Paulo, 1983) proved that the biggest linear measurements (AA'-Hy) were in Class III malocclusion patients which are in accordance with our findings.

**Conclusion**

The following conclusions were drawn:

1. Skeletal Class II malocclusion samples with retrognathic mandible showed an inferioposterior displacement of hyoid bone.
2. Skleletal Class III malocclusion samples with prognathic mandible showed a superioanterior displacement of hyoid bone. The positional alteration of hyoid was relevant to skeletal malrelationship.
3. The angular measurement hyoidale angle, hyoid plane angle and SND reveal a marked difference on comparing skeletal Class I, Class II and Class III malocclusion between each other.
4. Significant difference was found in anterioposterior linear dimension ($C_3$D and AA'-PNS) of pharynx in skeletal Class I, Class II and Class III malocclusion.

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