Cephalometric analysis of Hyoid bone position in different jaw dysplasias

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ABSTRACT

Background and Aim: Hyoid is the only bone that has no bony articulation. It is connected to muscles and ligaments. Therefore, its position can be associated with head posture and different oral functions. The aim of this study was to evaluate the hyoid bone position in different vertical and sagittal jaw dysplasias.

Materials and Methods: In this descriptive study, standard digital lateral cephalograms of 200 patients in the age range of 18 to 25 years were selected and subjects were divided into 5 groups based on vertical and horizontal facial growth pattern: group 1: Class I, normal face, group 2: Class II, normal face, group 3: Class III, normal face, group 4: Class I, short-faced, group 5: Class I, long-faced. Hyoid bone position was analyzed by View box4 software.

Results: The anterior-posterior position of the hyoid bone was significantly backward in groups 2 and 5 compared to groups 3 (P=0.001) and 4 (P=0.001). However, the sagittal position of this bone in groups 2 and 3 was comparable to groups 5 and 4. The vertical position of hyoid bone was significantly upward in groups 2 and 4 compared to groups 3 (P=0.001) and 5 (P=0.001) but this position was significantly downward in groups 2 and 5 compared to groups 4 (P=0.001) and 3 (P=0.001). The axial inclination of this bone was comparable among subjects with different sagittal jaw dysplasias. This inclination was significantly more horizontal in group 4 compared to group 1 whereas in group 5, hyoid bone was more oblique (P=0.001).

Conclusion: Among subjects with different sagittal jaw dysplasias, the anterior-posterior position of the hyoid bone in Class II and Class III subjects was more posterior-superior and anterior-inferior compared to Class I subjects. Among subjects with different vertical jaw dysplasias, the hyoid bone in groups 4 and 5 was more anterior-superior and posterior-inferior respectively compared to normal-faced subjects.

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Introduction

Based on the functional matrix theory, the shape and amount of bony growth is influenced by needs of surrounding soft tissue. Therefore, the increased or decreased growth of these bones including jaw bones is influenced by attached muscles and strong or weak function of these muscles. Effect of tongue on incidence or survival of some dental and skeletal malocclusions is obvious, but studies on muscles located inferior to tongue such as suprahyoid muscles and infrahyoid muscles and their effect on the shape, growth, external and internal angles of mandible have been less considered. Hyoid bone as a link between suprahyoid and infrahyoid muscles has a significant role in orientation and even in function of these muscles which should not be disregarded. 1, 2 Till now, limited number of studies have been performed on hyoid bone, for example the first study in this regard belongs to Brodie, 3 which evaluated the importance of hyoid bone in establishing head and neck balance. Also, for the first time, Ricketts mentioned the importance of hyoid bone position in breathing. 4 Cuccia et al. in evaluating oral breathing and head posture, noticed the downward position of hyoid bone (increased distance relative to mandibular plane) in oral breathers compared to the control group. 5 These findings were not in line with the results reported by Ferraz which stated that the position of hyoid bone is stable and is independent of any changes in position due to tongue thrusting and oral breathing. 6 Also, the inferior position of hyoid bone can be considered as one of the predictive skeletal indices for sleep apnea and this process can be considered as an attempt of body postural system for maintenance of airway space through increasing the inferior limit of oropharyngeal space by downward positioning of hyoid bone which during this process, tension of infrahyoid muscles dominates that of suprahyoid muscles. 7 In evaluation of developmental variations in position of hyoid bone, Shang et al. showed that in females, increased facial angle or increased ramus length dictates the superior position of hyoid bone which is opposite in males. 8 Adamis and Spyropoulos evaluated the position of hyoid bone in two groups with class I and class III malocclusions. The results showed that in class III individuals especially in boys hyoid bone had a more forward position and a reversed inclination which can influence the function of supra and infrahyoid muscles and also can influence the mandibular growth direction. 9 Rav-anmehr and Abdollahi evaluated the position of hyoid bone in skeletal class I, II and III patients and concluded that the mentioned bone in class III group has a more anterior position compared to the other groups. Also in class II group this bone has a more superior position compared to the other two groups. The results of the mentioned study showed that mandibular growth and development can be influenced by surrounding structures (such as correlated muscles) and intervention in amount and direction of its growth is probable through variation in these structures. 10 On the other hand, considering the correlation between mandibular bone and hyoid bone through geniohyoid, mylohyoid muscles and anterior belly of digastric muscle, variation in position of hyoid bone can be one of the therapeutic effects of functional orthopedic appliances. 11, 12 Nevertheless, correlation of this bone with vertical and anterior facial growth pattern and especially with anatomic changes in the lower 1/3 of the face and mandible is still ambiguous. The aim of the present study was the evaluation of hyoid bone position in different vertical and horizontal facial discrepancies because with confirmation of correlation between hyoid bone position and malocclusion and further studies for confirming the effect of hyoid bone on incidence of malocclusion, the position of hyoid bone can be used as a malocclusion predictive factor and with changing the position of this bone, secondary malocclusion can be prevented.

Materials and Methods

In this descriptive study, samples were chosen from among digital lateral cephalograms of the patients referring to an orthodontist’s office from 2010 to 2013. To obtain standard radiographs, the source-to-patient’s head distance was 150 cm and cephalograms were obtained under similar exposure parameters with Soredex x-ray system (Cranex-3D, Finland). All samples were in accordance to the inclusion criteria (according to patient’s file and lateral cephalogram). Age, history of orthodontic treatment, trauma, maxillofacial surgery, oral breathing, facial asymme-
try and syndromes and birth defects of samples were evaluated based on patients’ files. Finally, the samples without any of the mentioned factors and with standard digital radiographs of suitable quality with visible hyoid bone were chosen from among 18 to 25 year-olds. Sample size was determined to be at least 32 individuals in each group according to equation and 40 samples were assigned to each group with total sample size of 200 individuals (97 males and 103 females). Lateral cephalograms which were fixed on a negatoscope were photographed by Canon 450D digital camera on a stand, under similar light and in a semi dark room, from 70 cm distance and these photographs were converted to digital format. The obtained images were analyzed by viewbox 4 software. First, by computerized cephalometric analysis, the patients were divided to 5 groups of 40 based on Bjork Sum, FMA, Angle of convexity and ANB indices according to the presented table. View box 4 software was used for evaluation of hyoid bone position, which is an advanced cephalometric software which can determine the predefined landmarks or the new landmarks of interest on any type of radiograph, photograph or other two dimensional images. In addition, the advanced algorithms of this software provide image enhancement, ease in landmarks identification and morphometric analyses. Template-making and user-defined analyses are some of the advantages of this software. Therefore, a series of points, lines and angles were defined as a template for view box 4 software. The quality and magnification of each radiograph was edited by the software and then by using this software, 10 radiographs in each group were analyzed twice by two orthodontic residents. If controversy was present, the controversial points were jointly evaluated. Reliability assessment revealed that the correlation coefficient of these two measurements was 95%. Cephalometric points, lines and angles for determination of growth patterns and hyoid bone position were as follows:

A) Points
1. Sella (S): the center of the bony crypt occupied by the hypophysis which is identified visually
2. Orbitale (Or): the lower most part of the inferior orbital rim
3. Porion (Po): the midpoint on the upper edge of the external auditory meatus
4. Pterygoid vertical reference (Ptr): the most posterior area of the distal wall of pterygomaxillary fissure
5. Center of third cervical vertebra (C3C): center of third cervical vertebra which is formed by the junction of the diameters of this vertebra
6. Hyoidale (H): the most anterior-superior point on the body of the hyoid bone

<table>
<thead>
<tr>
<th>Growth pattern criteria</th>
<th>Bjork sum</th>
<th>FMA</th>
<th>Angle of convexity</th>
<th>ANB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: class I with normal facial height</td>
<td>390&lt;Sum&lt;402</td>
<td>20&lt;FMA&lt;27</td>
<td>0&lt;Aangle of convexity&lt;7</td>
<td>0&lt;ANB&lt;4</td>
</tr>
<tr>
<td>Group 2: class II with normal facial height</td>
<td>390&lt;Sum&lt;402</td>
<td>20&lt;FMA&lt;27</td>
<td>0</td>
<td>4 ≤</td>
</tr>
<tr>
<td>Group 3: class III with normal facial height</td>
<td>390&lt;Sum&lt;402</td>
<td>20&lt;FMA&lt;27</td>
<td>≤0</td>
<td>4 ≤</td>
</tr>
<tr>
<td>Group 4: class I with decreased facial height</td>
<td>≤390</td>
<td>≤20</td>
<td>0&lt;Aangle of convexity&lt;7</td>
<td>0&lt;ANB&lt;4</td>
</tr>
<tr>
<td>Group 5: class I with increased facial height</td>
<td>402≤</td>
<td>27≤</td>
<td>0&lt;Aangle of convexity&lt;7</td>
<td>0&lt;ANB&lt;4</td>
</tr>
</tbody>
</table>
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Varnishes

Figure 1- Points and lines in measurement of hyoid bone position

B) Lines
1. Frankfort horizontal plane (FH- plane): the horizontal line connecting Po and Or
2. Sella perpendicular (S per): the line perpendicular to FH plane from S point which is one of the vertical reference planes
3. Ptr perpendicular (Ptr per): the line perpendicular to FH plane from Ptr point which is the second vertical reference plane
4. C3C horizontal (C3C hor): horizontal plane crossing C3C point which is parallel to FH and perpendicular to two previous lines and is considered as horizontal reference plane.
5. Hyoid axis (H axis): line connecting H and G (figure 1)

C) Angles
1. N-S-Ar (Saddle angle): angle in S point formed by S-N (Nasion) and Ar (Articular)-S
2. S-Ar-Go (Articular angle): angle in Ar point formed by Ar-S and Go (Gonion)-Ar
3. Ar-Go-Me (Gonial angle): shows the angle between body and ramus of the mandible and is formed by the junction of Go-Ar and Me (Menton)-Go in Go point.
4. ANB: an angle in N point formed by N-A and B-N and shows the anterior-posterior maxillo-mandibular relation
5. FMA: an angle between FH plane and mandibular plane (Go-Me) which shows the inclination of mandibular body in relation to horizon.
6. Angle of convexity: an angle between N-A and A-Pog which shows the position of the anterior part of maxillary bony base in relation to overall facial profile

D) Variables in measurement of hyoid position: (figure 2)

Figure 2- Variables in measurement of hyoid bone position

1. H-S per distance: horizontal distance from H point to S per which shows the anterior-posterior position of H point.
2. H-Ptr per distance: horizontal distance from H point to Ptr per plane which shows the anterior-posterior position of H point. When H point is located more anterior in relation to S per andPtr per planes, measurements for the related distances are positive and for more posterior position of H point in relation to the reference planes, measurements are considered negative.
3. H-C3C hor distance: vertical distance from H point to C3C hor plane which shows the vertical position of H. When H and G points are located more superior in relation to C3C hor plane, measurements for the related distances are negative.
4. G-C3C hor distance: vertical distance from H point to C3C hor plane which shows the vertical position of H. When H and G points are located more superior in relation to C3C hor plane, measurements for the related distances are negative.
5. H axis-Ptr per angle: inferior-external angle
between H axis and Ptr per which shows the axial inclination of hyoid bone.
6. H axis-C3C hor angle: inferior-external angle between H axis and C3C hor which shows the axial inclination of hyoid bone.

Collected data were analyzed by SPSS version 20 statistical software.
One way ANOVA, LSD test and Pearson correlation coefficient were used for statistical analysis of data. The data are expressed with 95% confidence level. P<0.05 means that the result is statistically significant with the probability of 95% and p>0.05 means that the result is not statistically significant.

Results
Mean of the mentioned variables in different groups is presented in table 2.

<table>
<thead>
<tr>
<th>Groups</th>
<th>H-S per distance</th>
<th>H-Ptr per distance</th>
<th>H-C3C hor distance</th>
<th>G-C3C hor distance</th>
<th>H axis-Ptr per angle</th>
<th>H axis-C3C hor angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: class I with normal facial height</td>
<td>Mean 14.18 SD 1.85</td>
<td>Mean -2.48 SD 0.77</td>
<td>Mean 18.30 SD 1.23</td>
<td>Mean 5.83 SD 1.57</td>
<td>Mean 68.45 SD 1.25</td>
<td>Mean 21.55 SD 1.25</td>
</tr>
<tr>
<td>Group 2: class II with normal facial height</td>
<td>Mean 10.28 SD 3.43</td>
<td>Mean -4.85 SD 0.74</td>
<td>Mean 17.20 SD 1.34</td>
<td>Mean 5.19 SD 1.86</td>
<td>Mean 69.20 SD 2.59</td>
<td>Mean 20.99 SD 2.56</td>
</tr>
<tr>
<td>Group 3: class III with normal facial height</td>
<td>Mean 19.80 SD 9.52</td>
<td>Mean 3.35 SD 1.44</td>
<td>Mean 19.28 SD 1.51</td>
<td>Mean 6.38 SD 1.91</td>
<td>Mean 67.83 SD 2.73</td>
<td>Mean 22.18 SD 2.72</td>
</tr>
<tr>
<td>Group 4: class I with decreased facial height</td>
<td>Mean 20.23 SD 9.93</td>
<td>Mean 3.53 SD 1.40</td>
<td>Mean 13.28 SD 2.13</td>
<td>Mean 4.75 SD 2.17</td>
<td>Mean 75.30 SD 5.72</td>
<td>Mean 14.70 SD 5.72</td>
</tr>
<tr>
<td>Group 5: class I with increased facial height</td>
<td>Mean 10.43 SD 3.73</td>
<td>Mean -5.10 SD 1.57</td>
<td>Mean 23.08 SD 2.08</td>
<td>Mean 6.89 SD 1.52</td>
<td>Mean 66.75 SD 2.55</td>
<td>Mean 23.24 SD 2.55</td>
</tr>
</tbody>
</table>

One-way ANOVA showed that mean of H-S per distance, H-Ptr per distance, H-C3C hor distance, G-C3C hor distance, H axis-Ptr per angle and H axis-C3C hor angle were not similar in different groups, (P<0.001) in addition, the results obtained from two by two comparisons of mean of each variable among groups by LSD test are presented in table 3.
Discussion

Previous studies have used different methods for evaluation of hyoid bone position. Many of these studies have used the cranial structures for determination of reference planes in detection of hyoid bone position. Cranial reference planes are relatively far from hyoid bone and therefore, minimum variations in position or inclination of these reference planes can result in a major variation in hyoid bone position. Therefore, in the present study similar to the study by Jenaa a new method for evaluation of hyoid bone position with reference planes adjacent to hyoid bone was adapted. In the present study, the hyoid bone position was assessed in H and G points in relation to horizontal and vertical reference planes. In most studies, only H point has been considered but as different muscles are attached to the body and the greater horn of hyoid bone and the effect of muscles on these two points may be different or muscles originating from these points may have different effects on hyoid bone position, in the present study the position of each of these points was evaluated separately. Also in this study, sample size was larger than previous studies. In the present study, H-S per distance and H-Ptr per distance indices were used in horizontal dimension. The second index was used to confirm the results obtained by the first index. The comparative result between groups regarding H-S per distance shows that:

1. Groups 1, 2 and 3 showed significant differences compared to each other and hyoid bone in class II and III groups was more posterior and anterior respectively compared to class I subjects.
2. Groups 1, 4 and 5 showed significant differences compared to each other and hyoid bone in short-faced and long-faced subjects was more anterior and posterior respectively compared to normal-faced subjects,
3. In groups 2 (class II) and 5(long-faced) hyoid bone had a backward position and the difference between these two groups was not significant. All the above results were confirmed by the results obtained from inter-group comparison of H-Ptr per distance parameter.

In studies by Zhou et al. 12 and Ramia et al. 16 which treated class II patients with Frankel functional appliance and Twin block respectively, hyoid bone moved significantly forward. Also in studies by Turnbull and Battagel 17 and Gale et al. 18 similar results were obtained after surgical mandibular advancement. Considering these results, it can be concluded that forward movement

Table 3- P value obtained through two by two comparisons of horizontal, vertical and angular parameters

<table>
<thead>
<tr>
<th>Groups</th>
<th>H-S per distance</th>
<th>H-Ptr per distance</th>
<th>H-C hor distance</th>
<th>G-C hor distance</th>
<th>H axis-Ptr per angle</th>
<th>H axis-C-C hor angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 with group 2</td>
<td>*0.009</td>
<td>*0.001</td>
<td>*0.004</td>
<td>*0.030</td>
<td>0.457</td>
<td>0.450</td>
</tr>
<tr>
<td>Group 1 with group 3</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.011</td>
<td>0.148</td>
<td>0.400</td>
<td>0.399</td>
</tr>
<tr>
<td>Group 2 with group 3</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>0.114</td>
<td>0.111</td>
</tr>
<tr>
<td>Group 1 with group 4</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.005</td>
<td>*0.001</td>
<td>*0.001</td>
</tr>
<tr>
<td>Group 1 with group 5</td>
<td>*0.012</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.005</td>
<td>*0.023</td>
<td>*0.024</td>
</tr>
<tr>
<td>Group 4 with group 5</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
<td>*0.001</td>
</tr>
</tbody>
</table>
of mandible can cause hyoid to position more forward. 
The reason for hyoid bone movement in relation to mandibular movement can be explained considering the followings: 19

Hyoid bone is correlated to mandible through suprahypoid muscles (geniohyoid, mylohyoid and digastric muscles) and to sternum, scapula and thyroid cartilage through infrahyoid muscles and to cranium through stylohyoid and digastric muscles and these muscles move the hyoid “upward and forward”, “downward” and “upward and backward” respectively.

As geniohyoid muscle has the maximum potential for moving hyoid bone forward, 20 it may be concluded that in class III subjects, mandible is positioned more forward and considering the attachment of geniohyoid muscle to mandible, tension is created in these muscles and with transferring this tension to hyoid bone, the balance between supra and infra hyoid muscles is disrupted in favor of suprathyoid muscles and finally hyoid bone is moved forward. Nevertheless the reverse process is also possible i.e. tonicity and weakness of infra hyoid muscles allow more freedom of hyoid bone and allow more growth of mandible. 18

In the present study, H-C3C hor distance and G-C3C hor distance indices were used in vertical dimension. The second index was used to confirm the results obtained by the first index. The comparative result between groups regarding H-C3C hor distance shows that:

1. Groups 1, 2 and 3 showed significant differences compared to each other and hyoid bone in class II and III groups was more superior and inferior respectively compared to class I subjects,
2. Groups 1, 4 and 5 showed significant differences compared to each other and hyoid bone in short-faced and long-faced subjects was more superior and inferior respectively compared to normal-faced subjects

All the above results were confirmed by the results obtained from inter-group comparison of G-C3C hor distance parameter, but the difference was not significant between groups 1 and 3 which can be related to the unreliability of G point in identification of hyoid bone position due to obvious anatomical differences. The number of attached muscles to this point is way less than that of H point.

The results of the present study are similar to studies by Jenaa and Duggal. 21 They concluded that the vertical position of hyoid bone in short-faced subjects is a little higher than that of long-faced subjects and even that of individuals with normal facial height. This can be due to the different tensions of suprathyoid muscles when mandible is rotating upward and forward. In long-faced subjects, mandible rotates downward and backward and so does the hyoid bone or it is possible that the inferior position of hyoid bone or higher contraction of infrahyoid muscles and tension in suprathyoid muscles rotates the mandible downward and backward and causes facial hyper divergence. Therefore, it may be concluded that hyoid bone follows the craniofacial growth vector and moves forward and downward in a path similar to this vector. In a study by Eslami 22, hyoid bone had significantly moved downward after functional treatment, which confirms the confirmation of hyoid bone from mandibular position. Also, Ricketts proposed that in subjects with enlarged tonsil the inferior position of hyoid bone has a tendency to produce an oral airway. Nevertheless, factors like inferior tongue position, narrow posterior airway and excessive craniofacial inclination can be considered as important factors in inferior position of hyoid bone. 4

For evaluation of variations in axial inclination of hyoid bone, H axis of this bone was compared with vertical reference line Ptr per and horizontal reference line C3C hor. Comparison of groups regarding H axis-Ptr per angle revealed that:
1. Group 1 in comparison with groups 2 and 3 and also groups 2 and 3 in comparison with each other showed no significant difference, in other words, hyoid bone inclination is not correlated with skeletal classification which can be related to the normal vertical dimension of these three groups.
2. But the differences among groups 1, 4 and 5 were significant and hyoid bone in long-faced subjects was more inclined and in short-faced subjects was less inclined compared to subjects with normal face. In other words, hyoid inclination can be a function of facial divergence and with higher correlation a function of mandibular inclination.

The results of H axis-C3C hor angle comparison confirmed all of the above results.
Jena and Duggal found that in short-faced subjects hyoid bone is more horizontal while in long-faced subjects it is situated more oblique. In accordance to the mentioned study, it may be stated that due to the hyoid bone conformation of mandibular inclination, significant differences among groups 1, 2 and 3 cannot be anticipated.

**Conclusion**
In horizontal jaw dysplasias, the anterior-posterior position of hyoid bone in class II and III subjects was respectively more posterior-superior and more anterior-inferior compared to class I subjects.
In vertical jaw dysplasias, hyoid bone in short-faced and in long-faced subjects was respectively more anterior-superior and more posterior-inferior than subjects with normal facial height.
Hyoid bone inclination conforms of overall facial height and craniofacial growth divergence.

**Conflict of interests**
Authors report no conflict of interest related to this study.

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