Original Article

Assessment and correlation of the position and orientation of the hyoid bone in Class I, Class II, and Class III Malocclusions

ABSTRACT

Objective: This study aims to examine and correlate the position and orientation of the hyoid bone in Class I, Class II and Class III malocclusions.

Materials and Methods: A total of 90 pretreatment digital lateral cephalograms were chosen in accordance with the established criteria and categorized into three groups, namely: Class I (n = 30), Class II (n = 37), and Class III (n = 23) malocclusions. The lateral cephalograms were traced and various linear and angular parameters such as MPH, H-NL, H-Go, H-Me, H-FH, H-C3, NSH, and H-NL were measured. The standard deviation and arithmetic mean values were computed for every measurement, after which independent t-test was conducted to study the variations between the skeletal classes of malocclusions.

Results: The linear measurements of H-Me and H-C3 were found to be statistically significant. The angular measurements of SNA and ANB were also statistically significant and indicated the dissimilarities in the different classes of malocclusions. The anteroposterior position of hyoid bone was established, but the superoinferior positioning was found to be statistically insignificant.

Conclusion: A significant difference occurs in the position and orientation of Hyoid Bone in relation to its surrounding structures in Class I, II, and III malocclusions. The hyoid bone is more anteriorly placed in Class III malocclusions than Class II which is more posteriorly placed. The superoinferior positioning of hyoid bone was found to be statistically insignificant in this study.

Keywords: Growth patterns, hyoid position, orthodontics, skeletal malocclusion

INTRODUCTION

To ensure the success of an orthodontic or orthognathic treatment, an accurate diagnosis of the entire craniofacial region is essential. The entire treatment is customized for an individual based on the relation between the hard and soft tissues of the craniofacial region.

It has been recognized that there may be significant differences in physiologic function of individuals with different craniofacial anatomical relationships.[1] In orthodontics, cephalometric radiography has become one of the most essential tools for recognizing the craniofacial anatomical relationships. It has been utilized extensively to quantify the dental, skeletal, and soft tissue relationships of the craniofacial complex, before the beginning of orthodontic treatment and throughout growth. Less often, in clinical research, cephalometry is used to evaluate craniocervical

Aishwarya Prashant Gundawar, Deven Mahesh Rawlani, Amol S. Patil, Anand Sabane

Department of Orthodontics, Bharati Vidyapeeth Dental College and Hospital, Pune, Maharashtra, India

Address for correspondence: Dr. Aishwarya Prashant Gundawar, Department of Orthodontics, Bharati Vidyapeeth Dental College and Hospital, Pune-Satara Road, Katraj-Dhankawadi, Pune - 411 043, Maharashtra, India.
E-mail: gundawaraishwarya@gmail.com

Received: 21-Oct-2019 **Revised:** 07-Nov-2019
Accepted: 07-Nov-2019 **Published:** 17-Dec-2019

Access this article online	
Website: www.orthodrehab.org	Quick Response Code
DOI: 10.4103/ijor.ijor_18_19	

How to cite this article: Gundawar AP, Rawlani DM, Patil AS, Sabane A. Assessment and correlation of the position and orientation of the hyoid bone in Class I, Class II, and Class III Malocclusions. Int J Orthod Rehabil 2019;10:161-7.

angulation, pharyngeal relationships, soft palate dimensions, and hyoid bone and tongue position.[2-5] In recent times, the position of hyoid bone in relation to its surrounding structures has gained significant amount of attention.

The hyoid bone is a horseshoe-shaped bone situated in the anterior midline of the neck between the chin and the thyroid cartilage. At rest, it lies at the level of the base of the mandible in the front and the third cervical vertebra (C3) behind. The hyoid bone does not have a direct bony articulation with any other bone. It is suspended in the midline neck with muscles and ligaments from all directions. The hyoid bone serves as attachment to various muscles of the tongue, floor of the mouth, larynx, epiglottis, and the pharynx. It aids in various functions such as swallowing, breathing, and speech. It has also been related to obstructive sleep apnea (OSA) such that a more inferiorly positioned Hyoid bone increases the presence and severity of OSA. According to Brodie,[6] the upright posture of the head involves the balance between the tensions of posterior neck muscles and anterior muscles such as masticatory, suprahyoid, and infrahyoid groups in relative to occipital condyles. Hyoid bone position is, thus, a reflection of the relative tensions of the muscles, ligaments, and fascia attached to it.[7]

Various authors[8,9] have proved that the mandibular changes influence hyoid bone position during the entire postsurgical period, whereas stretching of suprahyoidal musculature seems to contribute to skeletal relapse. Being aware of the position of hyoid in different malocclusion and factors affecting its position can result in better orthodontic treatment without relapse and possible deficient pharyngeal airway space after orthodontic treatment as well as orthognathic surgery.[10]

Although similar studies have been performed before, disagreements over the position and orientation of hyoid bone still occur. This study aims to assess the position and orientation of the hyoid bone in Class I, II, and III malocclusions.

MATERIALS AND METHODS

The present study is an *in-vitro* retrospective study and did not involve any intentional radiation exposure to any patient.

Study population

A total of 90 pretreatment lateral cephalograms were selected from the records in the Department of Orthodontics, Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Pune. These radiographs were selected by simple random sampling after satisfying the established criteria of selection. Lateral cephalograms were taken by skilled and experienced technicians in a standard natural head position as recommended by Broadbent.[11] All cephalograms were printed from the same machine with unaltered standard settings of magnification and dimensions.

Criteria for selection

Inclusion criteria

- Good quality radiographs were selected
- Subject should be between the age group of 18–30 years
- Subject must not show any sign of previous orthodontic treatment.

Exclusion criteria

- The cephalograms with signs of trauma, congenital disease, cyst, tumors or any maxillofacial abnormality were excluded
- The radiographs of patients undergoing orthodontic treatment were excluded.

Method of data collection

- The 90 cephalograms were classified into three categories: Class I malocclusion, Class II malocclusion, and Class III malocclusion
- It was found that of a total of 90 cephalograms, 30 had Class I malocclusions, 37 had Class II malocclusions, and 23 had Class III malocclusions
- The cephalograms were traced by a single researcher using a lead pencil of 0.5 mm thickness and a millimeter scale for marking and measuring various points and planes on an orthodontic tracing paper. The angles were measured using a geometric protractor
- The cephalometric points and planes that were traced have been enumerated in Table 1. The linear and angular measurements that were recorded have been listed in Table 2. The schematic representation in the form of a tracing is shown in Figure 1
- All the linear measurements were recorded and the arithmetical mean of these readings was taken as the standard value for statistical evaluation
- All data collected was compiled, tabulated, and analyzed statistically
- The tests applied were independent *t*-test for analysis for variance and *post hoc* (Bonferroni) for multiple comparisons. The significance level was at $P < 0.05$.

RESULTS

- The resultant values obtained from the linear and angular measurement findings have been tabulated in Table 3
- The linear measurements of H-C3 and H-Me were statistically significant with their $P < 0.05$. The angular measurements of SNA and ANB were also statistically

Table 1: Cephalometric points and planes

Sym	Points and Planes	Description
S	Sella Turcica	A saddle shaped depression in the sphenoid bone containing the pituitary gland
Na	Nasion	The anterior-most point of the frontonasal suture
P	Porion	The midpoint of the upper margin of the external acoustic meatus
Or	Orbitale	The lower-most point on the inferior margin of the orbit
ANS	Anterior nasal spine	Spina nasalis anterior
PNS	Posterior nasal spine	Spina nasalis posterior
Point A	Subspinale	The deepest midline point on the premaxilla between the ANS and prosthion
Point B	Supramentale	The posterior-most point in the concavity between the infradentale and pogonion
Go	Gonion	The midpoint of the contour connecting the ramus and body of the mandible
Gn	Gnathion	The most anterior and inferior point on the symphysis of the mandible
Me	Menton	The most inferior point on the symphysis of the mandible
H	Hyoidale	The most anterosuperior point on the body of the hyoid bone
Hy′	Hy′ Point	The most posterior point of the greater horn of the hyoid bone
C3	3rd cervical vertebra	The most anteroinferior position on the third cervical vertebrae
SN	Sellanasion plane	The line connecting points S and N
FH	Frankfort horizontal plane	The line connecting points P and Or
MP	Mandibular plane	The line connecting points Go and Gn
NL	Nasal line	The line connecting points PNS and ANS
H axis	Hyoid axis	The line connecting points H and Hy′

S: Sella Turcica, P: Porion, Or: Orbitale, Go: Gonion, Gn: Gnathion, ANS: Anterior nasal spine, PNS: Posterior nasal spine, H: Hyoidale, Hy′: Hy′ Point

Table 2: Linear and angular cephalometric measurements

Sym	Description
NSH	The angle formed by joining NA, sella and H
MPH	The angle formed by joining Go, Gn and H
SNA	The angle formed by joining sella, NA and point A
SNB	The angle formed by joining sella, NA and point B
ANB	The angle formed by joining point A, NA and point B (ANB=SNA-SNB)
H-SN perpendicular	The linear distance along a perpendicular from H to the S-N plane
H-FH perpendicular	The linear distance along a perpendicular from H to the Frankfort plane
H-MP perpendicular	The linear distance along a perpendicular from H to the MP (Go-Gn)
H-NL perpendicular	The linear distance along a perpendicular from H to the palatal plane/NL
H-C3	The linear distance between H and C3
H-Me	The linear distance between H and Me
H-Go	The linear distance between H and the Go

H: Hyoidale, C3: 3rd cervical vertebra, SN: Sella-nasion plane, FH: Frankfort horizontal plane, MP: Mandibular plane, NL: Nasal line, Me: Menton, Go: Gonion, Gn: Gnathion, Na: Nasion

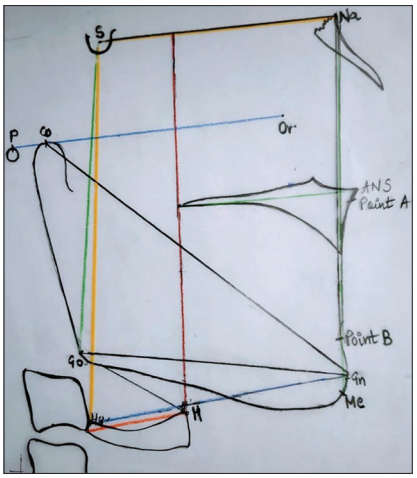

Figure 1: A tracing of a lateral cephalogram which shows all the cephalometric points, planes and landmarks related to this study of hyoid bone

significant and indicated the dissimilarities in the different classes of malocclusions. The *P* values have been tabulated in Table 4 for comparison

- These findings show that hyoid bone is more inferiorly placed in Class I malocclusions than Class II which is more superiorly placed. However, since the $P > 0.05$, the data are statistically not significant
- The position of hyoid in relation to mandible using H-Me and H-C3 as the parameters has shown that hyoid is more anteriorly placed in Class II malocclusion; and it is more posteriorly placed in Class I malocclusion [Figure 2]
- The linear measurement from cervical vertebra to the Hyoid was most in Class III and the least in Class I, which confirms the above finding. The distance from Menton to the hyoid bone was also least in Class III and most in Class I, which supports the more forward positioning of hyoid bone in Class III malocclusion patients.

DISCUSSION

In the early stages of life, the hyoid bone is placed at the inferior edge of mandibular border, but with the aging process, it gradually descends and eventually is fixed next to the fourth cervical vertebra (C4). The position of hyoid bone also differs as a result of any changes in the body gesture, head position and other physiological states. In addition, the hyoid bone moves in response to mouth's different functions such as respiration and ingestion.[12]

Extensive research has been conducted in order to identify the position of the hyoid bone in various dentofacial patterns. The studies have shown that changes in the position of the mandible are related to those in the hyoid bone and the position of hyoid bone adjusts to anteroposterior changes in the head posture.[13,14] Moreover, published studies

Table 3: Mean and standard deviation - Hyoid data

	Mean	SD
NSH		
Class I	89.3	5.4
Class II	89.85	4.42
Class III	87.5	1.32
Total	89.59	4.7
MPH		
Class I	27.86	9.49
Class II	27.18	10.81
Class III	27	7
Total	27.4	10.2
H-SN		
Class I	10.37	0.68
Class II	10.03	0.88
Class III	9.33	0.9
Total	10.12	0.84
H-FH		
Class I	8.19	0.62
Class II	7.86	0.8
Class III	7.36	0.97
Total	7.95	0.76
H-NL		
Class I	5.77	0.62
Class II	5.6	0.66
Class III	5.2	0.8
Total	5.64	0.65
H-MP		
Class I	1.37	0.61
Class II	1.37	0.59
Class III	1.23	0.87
Total	1.37	0.6
H-C3		
Class I	3.06	0.56
Class II	3.39	0.48
Class III	3.71	0.15
Total	3.48	0.53
H-Me		
Class I	7.7	0.89
Class II	7.05	0.95
Class III	7	0.45
Total	7.27	0.96
H-Go		
Class I	1.34	0.56
Class II	1.45	0.65
Class III	1.4	0.43
Total	1.41	0.61
SNA		
Class I	79.6	5.0
Class II	76.8	4.63
Class III	79.6	1.52
Total	78.67	3.72
SNB		
Class I	81.9	4.29
Class II	82	4.6
Class III	79	1
Total	80.97	3.30
ANB		
Class I	2.3	0.7
Class II	6.1	2.1
Class III	−0.67	1.15
Total	2.58	1.32

H: Hyoidale, C3: 3rd cervical vertebra, SN: Sella-nasion plane, FH: Frankfort horizontal plane, MP: Mandibular plane, NL: Nasal line, Me: Menton, Go: Gonion, SD: Standard deviation

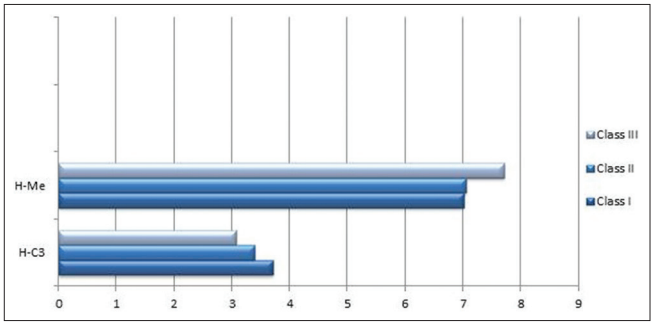

Figure 2: A chart comparing the position of the Hyoid bone in Class I, II and III malocclusions with respect to H-Me and H-C3

have determined that there is a strong relation between the hyoid bone position and the size of respiratory tract; therefore, great consideration has to be given to this before orthognathic surgery.[13,15-17]

In this study, a sample size of 90 lateral cephalograms was selected. These cephalograms were categorized into Class I, Class II, and Class III malocclusions. The cephalograms were traced, measured, and the values were tabulated. After statistical analysis, a conclusion was reached. In the course of the study it was found that, the linear measurements of H-C3 and H-Me were found to be statistically significant with their $P < 0.05$. The statistical values obtained show that hyoid bone is more posteriorly placed in Class I and more anteriorly placed in Class III malocclusion cases. The values for superoinferior positioning of hyoid bone were found to be statistically insignificant in this study, due to the P value being > 0.05. In the literature, several studies have been conducted in the past related to the positioning of hyoid bone.

Adamidis and Spyropoulos[18] studied the cephalometric radiographs of two groups exhibiting Class I and Class III malocclusions. He found that hyoid bone tends to be more anteriorly placed in the group exhibiting Class III malocclusions, which was similar to our study. Opdebeeck *et al*.[19] analyzed and compared linear and angular

Table 4: *Post hoc* test results - Hyoid data

Dependent variable	Class (I)	Class (J)	*P*
NSH	Class I	Class II	0.86
		Class III	0.8
	Class II	Class I	0.86
		Class III	0.67
	Class III	Class I	0.8
		Class II	0.67
MPH	Class I	Class II	0.95
		Class III	0.98
	Class II	Class I	0.95
		Class III	0.99
	Class III	Class I	0.98
		Class II	0.99
H-SN	Class I	Class II	0.16
		Class III	0.09
	Class II	Class I	0.16
		Class III	0.32
	Class III	Class I	0.09
		Class II	0.32
H-FH	Class I	Class II	0.12
		Class III	0.16
	Class II	Class I	0.12
		Class III	0.5
	Class III	Class I	0.16
		Class II	0.5
H-NL	Class I	Class II	0.52
		Class III	0.32
	Class II	Class I	0.52
		Class III	0.54
	Class III	Class I	0.32
		Class II	0.54
H-C3	Class I	Class II	0.02
		Class III	0.09
	Class II	Class I	0.02
		Class III	0.52
	Class III	Class I	0.09
		Class II	0.52
H-Me	Class I	Class II	0
		Class III	0.41
	Class II	Class I	0
		Class III	0.99
	Class III	Class I	0.41
		Class II	0.99
H-Go	Class I	Class II	0.7
		Class III	0.98
	Class II	Class I	0.7
		Class III	0.98
	Class III	Class I	0.98
		Class II	0.98
H-MP	Class I	Class II	1
		Class III	0.91
	Class II	Class I	1
		Class III	0.91
	Class III	Class I	0.91
		Class II	0.91
SNA	Class I	Class II	0.0
		Class III	0.01
	Class II	Class I	0.0
		Class III	0.0
	Class III	Class I	0.01
		Class II	0.0
SNB	Class I	Class II	0.98
		Class III	0.53
	Class II	Class I	0.98
		Class III	0.48
	Class III	Class I	0.53
		Class II	0.48
ANB	Class I	Class II	0.03
		Class III	1.0
	Class II	Class I	0.03
		Class III	0.57
	Class III	Class I	1.0
		Class II	0.57

H: Hyoidale, C3: 3rd cervical vertebra, SN: Sella-nasion plane, FH: Frankfort horizontal plane, MP: Mandibular plane, NL: Nasal line, Me: Menton, Go: Gonion

measurements for short face and long face syndrome and concluded that the characteristics of the long face and short face syndrome group can be explained by movement of hyoid bone in concert with the movement of mandible, tongue, and cervical spine in both groups.

Amayeri[20] observed that the hyoid bone is more inferiorly placed in Class III malocclusion, compared to Class II, where it is more superiorly placed. Lngervall *et al*.[21] only used the mandible as a reference for the comparison which is not a stable landmark which was further changed by Bibby and Preston[7] in the introduction of the hyoid triangle. Graber[22] on the other hand found the correlation between the position of the hyoid bone and and the mandibular morphology and hence found an affirmative explanation between the positive correlation. Stepovich[23] also said that the hyoid bone assumes variable position from a person to another, and the difference in it may also occur in a same sample of the patients after a short space of time. That is why the relation between the mandibular symphysis and the 3rd cervical vertebrae was considered into the relation by Bibby and Preston.[7]

The lower hyoid position in Class III malocclusion in relation to the anterior cranial base (SN plane) and the Frankfort plane (FH plane) could justify that the hyoid bone did not follow the mandibular movements completely. Thus it appears that, as the mandible is moved posteriorly in relation to the other craniofacial structures, the tongue and the hyoid bone do not follow this movement in a similar manner. Otherwise it would encroach upon the vital oropharyngeal and laryngeal

spaces. As a functional compensation, the hyoid bone and related structures are guided to an inferior position to avoid compromising the airway space. This suggests the stability and potency of the pharyngeal airway are primary factors in the hyoid bone position. This is consistent with the results of Tourné[24] and Battagel *et al*.[25]

An increase in the distance between the hyoid bone and the cervical vertebrae (C3) in Class III subjects were similar to the study conducted by Trenouth and Timms[26] and also Abu Alhaija *et al*.[27] that showed that the hyoid bone moves more posteriorly with the increase in ANB angle. The explanation of this phenomenon lies with the genioglossus muscle that protrudes the tongue and generates upper airway dilating forces to maintain the patency and as the hyoid bone moved forward would pull the tongue anteriorly en mass, leading to increase in tongue pressure and maintaining the pharyngeal spaces at the level of the base of the tongue.

In a study by Jose *et al*. in 2015, it was concluded that the position of hyoid bone in antero-posterior dimensions does not have any statistical difference among individuals with skeletal I, II and III patterns.[28] In a study by Kim *et al*. in 2016, it was concluded the Hyoid bone was more antero-inferiorly placed in Class III malocclusions and it was more postero-superiorly placed in Class II malocclusions.[10]

The position of the Hyoid bone in class III patients is more anteriorly and inferiorly placed due to the prognathic mandible and the pull from the suprahyoid and the tongue muscles attaching to the Hyoid. In Class II malocclusions, the mandible is more posteriorly positioned and the pull from the supra hyoid muscles is lesser. Thus, the hyoid is more posteriorly and superiorly placed.

If the hyoid bone is in the same position before and after orthodontic treatment, the soft tissue must still be in the same balance, thus possibly reducing the chance of relapse from the soft tissue forces. If the hyoid position is altered, a longer retention period than normal may be indicated. Any alteration in the hyoid position following mandibular surgery may be indicated for the balancing of the muscles forces to be made more favorable by myectomy or myotomy to reduce surgical relapse.[10]

The hyoid bone is a mobile structure which changes position with various physiologic processes such as swallowing, speech, or respiration. This study lacked the potential to assess the hyoid bone while in function. We promote further research for a more accurate assessment of hyoid bone position and orientation in different skeletal malocclusions.

CONCLUSION

A significant difference occurs in the position and orientation of hyoid bone in relation to its surrounding structures in Class I, II, and III malocclusions.

- In Class II malocclusion, the hyoid bone is placed more anteriorly, while in Class I malocclusions, it is positioned more posteriorly. It is positioned most anteriorly in Class III malocclusion cases
- In Class I malocclusion, the hyoid bone is more inferiorly placed as compared to Class II and III malocclusions. However, these data are statistically insignificant in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Ferraz MJ, Nouer DF, Teixeira JR, Bérzin F. Cephalometric assessment of the hyoid bone position in oral breathing children. Braz J Otorhinolaryngol 2007;73:45-50.
2. Ceylan I, Oktay H. A study on the pharyngeal size in different skeletal patterns. Am J Orthod Dentofacial Orthop 1995;108:69-75.
3. Haralabakis NB, Toutountzakis NM, Yiagtzis SC. The hyoid bone position in adult individuals with open bite and normal occlusion. Eur J Orthod 1993;15:265-71.
4. Kollias I, Krogstad O. Adult craniocervical and pharyngeal changes – A longitudinal cephalometric study between 22 and 42 years of age. Part I: Morphological craniocervical and hyoid bone changes. Eur J Orthod 1999;21:333-44.
5. Lyberg T, Krogstad O, Djupesland G. Cephalometric analysis in patients with obstructive sleep apnoea syndrome. I. Skeletal morphology. J Laryngol Otol 1989;103:287-92.
6. Brodie AG. Anatomy and physiology of head and neck musculature. Am J Orthod 1950;36:831-44.
7. Bibby RE, Preston CB. The hyoid triangle. Am J Orthod 1981;80:92-7.
8. Efendiyeva R, Aydemir H, Karasu H, Toygar-Memikoğlu U. Pharyngeal airway space, hyoid bone position, and head posture after bimaxillary orthognathic surgery in class III patients: Long-term evaluation. Angle Orthod 2014;84:773-81.
9. Eggensperger N, Smolka W, Iizuka T. Long-term changes of hyoid bone position and pharyngeal airway size following mandibular setback by sagittal split ramus osteotomy. J Craniomaxillofac Surg 2005;33:111-7.
10. Kim J, Raval N, Patil A. The evaluation of hyoid bone in different skeletal malocclusions and growth patterns in Indian population. Int J Adv Res 2016;4:876-87.
11. Broadbent B, Holly Sr, Broadbent B, Holly Jr and Golden W H. Bolton Standards of Dentofacial Developmental Growth. Saint Louis, USA: C.V. Mosby Company; 1975.
12. Mortazavi S, Asghari-Moghaddam H, Dehghani M, Aboutorabzade M, Yaloodbardan B, Tohidi E, *et al.* Hyoid bone position in different facial skeletal patterns. J Clin Exp Dent 2018;10:e346-51.
13. Sahoo NK, Jayan B, Ramakrishna N, Chopra SS, Kochar G. Evaluation of upper airway dimensional changes and hyoid position following mandibular advancement in patients with skeletal class II malocclusion.

J Craniofac Surg 2012;23:e623-7.
14. Güven O, Saraçoğlu U. Changes in pharyngeal airway space and hyoid bone positions after body ostectomies and sagittal split ramus osteotomies. J Craniofac Surg 2005;16:23-30.
15. Tarkar JS, Parashar S, Gupta G, Bhardwaj P, Maurya RK, Singh A, *et al.* An evaluation of upper and lower pharyngeal airway width, tongue posture and hyoid bone position in subjects with different growth patterns. J Clin Diagn Res 2016;10:ZC79-83.
16. Jiang YY. Correlation between hyoid bone position and airway dimensions in Chinese adolescents by cone beam computed tomography analysis. Int J Oral Maxillofac Surg 2016;45:914-21.
17. Yao K, Wang M, Yu W, Lu X. Study on the short-time remolding of upper airway after uvulopalatopharyngoplasty. J Craniofac Surg 2017;28:688-92.
18. Adamidis IP, Spyropoulos MN. Hyoid bone position and orientation in class I and class III malocclusions. Am J Orthod Dentofacial Orthop 1992;101:308-12.
19. Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D. Comparative study between the SFS and LFS rotation as a possible morphogenic mechanism. Am J Orthod 1978;74:509-21.
20. Amayeri, M. The position of hyoid bone in different facial patterns: A lateral cephalometric study. Eur Sci J 2014;10:15.
21. lngervall B, Carlsson GE, Helkimo M. Changes in location of the hyoid bone with mandibular positions Acta Odontol 1970;28:337.
22. Graber LW. Hyoid changes following orthopedic treatment of mandibular prognathism. Angle Orthod 1978;48:33-8.
23. Stepovich ML. A cephalometric positional study of the hyoid bone. Am J Orthod 1965;51:882-900.
24. Tourné LP. Growth of the pharynx and its physiologic implications. Am J Orthod Dentofacial Orthop 1991;99:129-39.
25. Battagel JM, Johal A, L'Estrange PR, Croft CB, Kotecha B. Changes in airway and hyoid position in response to mandibular protrusion in subjects with obstructive sleep apnoea (OSA). Eur J Orthod 1999;21:363-76.
26. Trenouth MJ, Timms DJ. Relationship of the functional oropharynx to craniofacial morphology. Angle Orthod 1999;69:419-23.
27. Abu Alhaija E, Al Wahadni A, Al Omari M. Uvulo-glossopharyngeal dimensions in subjects with β – Thalassaemia major. Eur J Orthod 2002;24:699-703.
28. Jose NP, Shetty S, Mogra S, Shetty VS, Rangarajan S, Mary L. Evaluation of hyoid bone position and its correlation with pharyngeal airway space in different types of skeletal malocclusion. Contemp Clin Dent 2014;5:187-9.